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A study of important principles of physical science...

A STUDY OF IMPORTANT PRINCIPLES OF PHYSICAL SCIENCE DEVELOPED IN GRADES SEVEN THROUGH TWELVE OF A TOWN IN MASSACHUSETTS WITH APPLICATIONS OF THOSE PRINCIPLES IN SEVEN LOCAL INDUSTRIES

by

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SURVEY OF RELATED LITERATURE

INTRODUCTION

The results of numerous investigations and experiences were reported by the committee on science of the National Society of the Study of Education in 1932 in its Thirty-First Yearbook.[1] The major aim of general education set forth in this report is life enrichment. The committee members agree that this goal can be accomplished by developing an understanding of principles, or generalizations, that have proven the most important during the evolution of mankind.[2] It was further emphasized by the committee that a program in science for general education should be formulated around the principles, or generalizations, that are functional in the lives of girls and boys.[3]

The committee on science also recommends that facts should be taught as an aid to facilitate the functional understanding of principles and to promulgate the development of their associated scientific attitudes.[4]

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[1] A Program for Teaching Science, Thirty-First Yearbook of the National Society for the Study of Education, Part I, Bloomington, Illinois: Public School Publishing Company, 1932.

[2] Ibid., p. 43.

[3] Ibid., p. 43.

[4] Ibid., p. 43.

In 1938, the Thayer Commission on Secondary School Curriculum of the Progressive Education Association published the report of its findings pertaining to the function of science in general education.[5] This commission propounds the idea that science teaching should be guided toward satisfying the needs which are demonstrated in the basic aspects of living. Moreover, the interests of pupils should also serve as a guide for the selection of subject matter for the instruction of science.[6]

The Thayer Commission further states that the developing of interpretational understandings as a goal in science teaching should result in a notable change in the individual's behavior.[7] This commission refers, moreover, to a generalization of science as, "an interpretive understanding" while the Thirty-First Yearbook Committee calls the same generalization a principle.

The reports of these two groups agree, nevertheless, that the major goal of science instruction at all grade levels of general education is a functional understanding of scientific principles.

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[5]Progressive Education Association, Commission on Secondary School Curriculum, Science in General Education. New York: D. Appleton-Century Company, 1938.

[6]*Ibid.*, p. 27.

[7]*Ibid.*, p. 55.

SURVEY OF IMPORTANT RESEARCH STUDIES PERTAINING TO THE DETERMINATION OF PRINCIPLES AS OBJECTIVES OF SCIENCE TEACHING

In 1925, Downing[8] published the opinion that the solving of a scientific problem progresses in three stages: (1) the accumulation of facts, (2) discovery of the apparent relation and sequence of these facts reduced to principles, and (3) the discovery of the approximate causes that are amenable to laws, or generalizations.

Craig[9], in planning a course of study in science for the elementary grades, stated, "the problem in the elementary school in regard to science is not so much that of training boys and girls to become scientists, as it is of helping them to become intelligent laymen." To accomplish this purpose, a course of study should be instigated that will develop certain objectives that agree with the facts, principles, generalizations, and hypotheses of science that are essential in the understanding of natural phenomena which challenge and intrigue children.

In a study to determine the amount of space in textbooks devoted to principles of science, Heinemann[10] selected

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[8]Elliot R. Downing, _Teaching Science in the Schools_, p. 53. Chicago: University of Chicago Press, 1925.

[9]Gerald S. Craig, _Certain Techniques Used in Developing a Course of Study in Science for the Horace Mann Elementary School_, Teachers College Contribution to Education, Number 276, pp. 12-13. New York: Teachers College, Columbia University, 1927.

[10]Ailsie M. Heinemann, "A Study of General Science Textbooks," _General Science Quarterly_, XIII (November, 1928), 11-23.

and analyzed twenty textbooks of general science. This study defined a principle as a "statement of relationship frequently causal in nature between two facts." A total of ninety-three principles was found in the twenty books. However, it was found that slightly more than twelve per cent of the entire reading space was consigned to principles. The authors of these selected books treated principles very briefly, and demonstrated little agreement as to the most important principles. This study recommended that fewer principles with many applications accomplished better teaching than a great many principles with but few applications.

Downing[11], in 1934, surveyed more than one dozen masters' theses compiled at the University of Chicago and selected from them a total of ninety-six principles considered necessary in biology, chemistry and physics. These principles were classified, and were arranged in order of importance as determined by the amount of subject matter each principle employed to derive it intelligibly.

An attempt was made by Robertson[12] in 1934 to determine the important science principles which are suitable as goals of instruction in general education grades I-VI, inclusively. The study, an extensive investigation of four masters' theses

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[11]Elliot Rowland Downing, An Introduction to the Teaching of Science, pp. 39-48. Chicago: University of Chicago Press, 1934.

[12]Martin L. Robertson, "The Selection of Science Principles Suitable as Goals of Instruction in Elementary Science," Science Education, XIX (February, 1935), 1-4; (April, 1935), 65-70.

and another unpublished study from the University of Michigan and three published studies by Downing and two other unpublished studies from the University of Chicago were analyzed to obtain lists of major and minor principles. Criteria for a principle were determined, and those principles which did not fit were discarded. Criteria used in this study follows: "To be a principle, a statement

Must be a comprehensive generalization
Must be true without exception within the limitations specifically stated
Must be a clear statement of a process or interaction
Must be capable of illustration so as to gain conviction
Must not be a part of a larger principle
Must not be a definition
Must not deal with a specific substance or variety or with a limited group of substances or species.

A total of 243 principles which conformed to the above criteria were obtained. This list of principles was presented to fifteen science teachers who checked them using a five point scale to determine their appropriateness as teaching goals in the elementary grades. The evaluators concluded that many of the principles were unsuited for comprehension in the lower grades. Hence, the final list comprised 113 principles suitable as goals of instruction for inclusion with grades I to VI.

A study to determine the concepts and generalizations in the field of chemistry which are of most distinctive

value to man in the interpretation of his environment was made by Pruitt[13]. Over fifty thousand pages of material including issues of three popular literary magazines, issues of four popular scientific magazines and one chemical journal, questions from three nationally known examinations, numerous volumes on various phases of science, stressing chemistry, and one year's issue of several newspapers were perused. By using the criteria similar to the ones which Robertson formulated previously, a final list of 135 generalizations relating to chemistry was arranged in order of their importance.

Wise[14] instituted an extensive and comprehensive investigation of the principles of the physical sciences. He developed the following criteria, also similar to those of Robertson but more concise:

> To be a principle a statement must be a comprehensive generalization describing some fundamental process, constant mode of behavior, or property relating to natural phenomena.
> It must be true without exception within limitations specifically stated.
> It must be capable of illustration.
> It must not be a definition.

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[13]Clarence Martin Pruitt, An Analysis, Evaluation, and Synthesis of Subject-Matter Concepts and Generalizations in Chemistry. Doctor's dissertation, Teachers College, 1935. Distributed through Science Education. See Third Digest of Investigations in the Teaching of Science by Francis D. Curtis. Philadelphia: P. Blakiston's Son and Co., Inc., 1939.

[14]Harold E. Wise, "A Determination of the Relative Importance of Principles of Physical Science for General Education," Science Education, XXV (December, 1941), 371-79; XXVI (January, 1942), 8-12; XXVII (February, 1943), 67-76; XXVII (September-October, 1943), 67-76.

By employing a reliable technique, Wise[15] formulated a defensible list of 272 principles of physical science by using the individual lists developed by Arnold, Hartman and Stephens, Pruitt, and Robertson. Of these 272 principles, 264 were arranged in the relative order of importance for general education grades I-XIV, inclusive. This composite list of principles included principles of chemistry, geology, and physics, including astronomy and meteorology.

The Thirty-First Yearbook Committee recommended that any assignment of scientific generalizations to definite grade levels be considered in terms of increasingly enlarged and matured concepts of certain principles established as goals of instruction at every level of development. Consequently, this study by Wise represents a partial solution to the problem insofar as it established the important principles found in the field of the physical sciences.

Reek[16] made an investigation of four series of textbooks of science written specifically for grades I through VI to determine what principles of science are found in

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[15]Harold E. Wise, A Determination of the Relative Importance of Principles of Physical Science for General Education. Unpublished Doctor's dissertation, University of Michigan, 1941.

[16]Doris Lucille Reek, A Study of the Principles of Science Found in Four Series of Textbooks of Elementary Science. Unpublished Master's thesis, University of Michigan, 1943.

the elementary grades. It was found that authors of these books did not treat principles as the Thirty-First Yearbook Committee had suggested and that the authors stress physical rather than biological principles. Some of these authors did not attempt to use principles at all.

Martin[17] made a comprehensive investigation of the principles of biological science in 1944. The following criteria for a principle were assigned in this study:

> (1) It must be a comprehensive generalization which resumes the widest possible range of facts within the domain of facts with which it is directly concerned. The facts resumed in the generalization must denote:
> a. Objects and/or events and the relation between them.
> b. Properties.
> (2) It must be scientifically true. To satisfy this criterion:
> a. It must be verifiable; i.e. it must be stated so that it suggests, directly or indirectly, a definite operation of observations or experiments whereby its truth value can be tested or verified.
> b. It must be consistent with the body of accepted scientific knowledge, and except for a few limiting or singular exceptions, with all the data (facts) relevant to it.

Martin helped to solve further the problem expounded by the Thirty-First Yearbook Committee in determining a defensible list of 300 principles related to the field of

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[17]W. Edgar Martin, "A Determination of the Principles of the Biological Sciences of Importance for General Education," Science Education, XXIX (March, 1945), 100-105; XXIX (April-May, 1945), 152-163; XXIX (February, 1945), 45-52.

W. Edgar Martin, "A Chronological Survey of Published Research Studies Relating to Biological Materials in Newspapers," School Science and Mathematics, XLV (June, 1945), 543-550.

the biological sciences. This study maintained the use of the same reliable technique used previously by Wise who had already devised his list of principles which related to the field of physical science; thus, with this new list of Martin's biological principles the problem was solved for establishing certain principles of science to be used as teaching goals for general education at all grade levels.

Fleish[18] made a survey based upon the scientific interests of pupils in grades VII through XII in four communities in Massachusetts to determine those science principles which should become the knowledge objectives of the general-science course. A list of sixty principles was based upon numerous questions submitted by pupils. Ten textbooks of general science were analyzed to determine which of the sixty principles were contained within them. It was found that although many of the textbooks did include most of the listed principles, these generalizations were not stated clearly or concisely.

Jones[19] analyzed seven textbooks of ninth-grade general science to determine the principles of science found in textbooks compiled after the publication of the Thirty-First Yearbook. A list of 146 principles governed by these

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[18] Sylvia Fleish, The Formulation of the Science Principles That Should Become the Objectives of General Science Teaching in the Junior High School. Unpublished Master's thesis, Boston University, 1945.

[19] Ruth V. Jones, A Study of the Principles of Science Found in Ninth Grade Textbooks of General Science. Unpublished Master's thesis, University of Michigan, 1946.

criteria was selected: A principle is a comprehensive generalization which

> Is stated definitely, not inferred.
> Is true but with rare exceptions within the limitations set by the statement.
> Is a clear statement of a dynamic process or of an interaction.
> Is not merely a definition or a description.
> Is demonstrable experimentally.
> Does not deal with specific substances or varieties.
> Has meaning outside of the context.

Jones' study discloses that the proven value of organizing the subject matter in terms of principles has not been recognized by the authors of textbooks. This study also deduced that a wide diversity in the number of principles was apparent, and that very little agreement existed as to what the authors should inculcate in a ninth-grade textbook of general science.

Miles[20] using Wise's list of 272 principles of physical science made a study in 1947 to determine which of these principles seemed desirable for inclusion in an integrated course of physical science for grades X-XII, inclusive. Five specialists in the field of the teaching of science marked Wise's list of principles into three categories: (1) Essential for inclusion in an integrated course of physical science for the senior high school, (2) Desirable if time permits, and (3) Undesirable for inclusion in such a course.

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[20]Vaden W. Miles, an unpublished study without title, University of Michigan, 1947.

Forty principles were deemed to be essential for this course by all five evaluators. Forty-six principles were marked essential by four and desirable by one of the five evaluators. Seventeen principles were marked essential by three and desirable by two of the five judges. Therefore, 103 of Wise's 272 principles were at least considered to be essential by a majority of the evaluators for inclusion in an integrated course of physical science for the senior high school.

Bergman[21] at New York University in 1946 completed a study in determining the principles of entomology of significance in general education. An analysis of ten general entomological textbooks and thirty reference books dealing with specific aspects of entomology, seven popular entomological textbooks, and 140 research bulletins and pamphlets resulted in forty-one major principles and five minor principles pertaining to entomology. These forty-six principles were then analysed by fifteen experts in the field of entomology, and were combined or were modified by addition into a final list of fifty-two principles of entomology. A comparison of the fifty-two principles of entomology and forty-five principles of biology obtained from the three preceding studies of Martin, Downing, and Winokur, revised, modified and clarified according to their wording within eight

[21]George J. Bergman, "A Determination of the Principles of Entomology of Significance in General Education," Science Education, XXXI (February, 1947), 23-32.

textbooks of biology recommended by fifteen department heads of high school biology, resulted in the discovery that (1) a major principle of entomology need not be related to, or based upon a major principle of biology, and (2) that a major fundamental principle of entomology may be based upon a minor, or a subordinate principle of biology.

The concluding article reporting Bergman's study did not appear in the literature in time to be included here.

SURVEY OF IMPORTANT RESEARCH STUDIES PERTAINING TO THE EFFECTIVENESS OF TEACHING PRINCIPLES IN TERMS OF THE RETENTION OF LEARNING

For the purpose of determining the relative retention by pupils of factual knowledge, their ability to explain every day happenings, and their ability to generalize from facts, a battery of three tests was administered to a group of ninth-grade pupils four months, and again twelve months, after completion of a course in general science. One test required knowledge of scientific facts; a second tested the ability to explain commonly seen phenomena; and a third tested the ability of the pupil to generalize from given facts. The findings in this study reported by Tyler[22] demonstrated that there was considerable loss in the remembering of facts, and that there was little loss in the ability to explain the phenomena that occur every day and the ability to generalize from facts.

[22]Ralph W. Tyler, "What High School Pupils Forget," Educational Research Bulletin, Ohio State University, IX (November 19, 1930), 490-492.

Johnson[23], University of Minnesota, conducted a study of an objective test which was given to three groups of elementary botany students at the end of three, fifteen, and twenty-seven months, respectively, following completion of the course. The results of these tests pointed out that there is a rapid loss in factual knowledge between the three and the fifteen month period while there is a very gradual loss after fifteen months.

In a study at Ohio State University, Wert[24] gave six tests to all the students in the elementary zoology classes to determine their retention of particular knowledge, abilities, and skills. During May in the three following years similar tests were again administered to those students who had taken the elementary course, but who had not continued in the field of zoology to determine the amount of learning that had been retained at the end of the one, two and three year period following the completion of the course. The results of this work indicate that factual memory decreased progressively with each year, but, however, no loss resulted in the application of principles to the solution of new problem situations. This ability to apply principles increases with the passage of time.

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[23]Palmer O. Johnson, "The Permanence of Learning in Elementary Botany," _The Journal of Educational Psychology_, XXI (January, 1930), 37-47.

[24]Jame E. Wert, "Twin Examination Assumptions," _Journal of Higher Education_, VIII (March, 1937), 136-140.

In a similar investigation[25] at Ohio State University, eighty-two students who studied the elementary zoology course were given a test for the retention of factual knowledge fifteen months after the completion of their course. It was found that the students had forgotten much of the factual knowledge while for the same period of time their ability to apply scientific principles to solve new problem situations had increased.

A study was made to ascertain the amount of retention of definite knowledge, abilities, and skills gained from studying a course in high school chemistry. A pre-test of five tests was given at the beginning of the course. The same five tests were again administered at the termination of the course; then, for a third time, these five tests were administered one year after the termination of the course. The five tests were built to test the knowledge of chemical facts, symbols, terminology, formulas and valence, balance of equations, and the application of principles. In this study, Frutchey[26] concluded that the greatest amount of retention was in the application of principles.

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[25] Ralph W. Tyler, "Permanence of Learning," Journal of Higher Education, IV (April, 1933), 203-204.

[26] F. P. Frutchey, "Retention in High School Chemistry," Educational Research Bulletin, Ohio State University, XVI (February, 1937), 34-37.

SURVEY OF IMPORTANT RESEARCH STUDIES PERTAINING TO THE DETERMINATION OF APPLICATIONS TO BE USED FOR DEVELOPING AN UNDERSTANDING OF PRINCIPLES OF SCIENCE

Pieper[27] indicated in the Thirty-First Yearbook that the specific human behaviors to which science study at the junior-high-school level may contribute are of two kinds: (1) Those which satisfy mental curiosity regarding phenomena and applications in the scientific fields, and (2) Those which include "practical" work, or activities in everyday life.

Wise, in the study of principles of physical science, suggested criteria for the selection of applications to conform to present opinion as to the purpose and function of general education by emphasizing the practical and cultural aspects of science. Accordingly, these criteria are: An application shall be considered to be a suitable one if, in the opinion of the investigator, it

A. Represents a problematic situation involving in its solution an understanding of one or more of the principles of physical science;
B. Suggests information which in itself would be of practical value in daily life apart from vocational or professional interests, or which would possess cultural value to the average citizen apart from practical value.[28]

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27 A Program for Teaching Science, Thirty-First Yearbook of the National Society for the Study of Education, Part I, p. 157. Bloomington, Illinois: Public School Publishing Company, 1932.

28 Harold W. Wise, "A Determination of the Relative Importance of Principles of Physical Science for General Education," Science Education, XXV (December, 1941), 371-379; XXVI (January, 1942), 8-12.

These criteria resulted in 3,403 applications assigned to principles in the analysis of eleven textbooks. The applications found were then assigned to four teachers of science for perusal of (1) adherence to criterion of cultural and practical value, (2) assignment involving in their explanations the applications to principles, (3) possible duplication of any application under a single principle. A resulting total of 3,103 applications were assigned to 246 out of 272 physical science principles.

SUMMARY OF RESEARCH STUDIES

A review of the preceding investigations and surveys is indicative that generalizations and principles of science are justified and recognized as objectives of science teaching at all grade levels for general education.

Downing, University of Chicago, is credited with the first emphasis on generalizations as goals for science instruction in general education. His study produced a generally rapid shift from factual indoctrination itself to the use of facts as an aid to the formulation of generalizations which can be employed in solving new problem situations.

Curtis, University of Michigan, receives credit for directing the researches by Robertson, Wise, and Martin in establishing the more essential principles that should be of value at all levels of general education. Robertson's

study was used by Wise and Martin in compiling their defensible lists of physical science principles, and biological science principles, respectively.

These two extensive studies established a definite concept of a principle by employing similar criteria to determine the scientific principles to be taught in all fields of science in general education, grades I through XIV.

Tyler, Johnson, Wert, and Frutchey amassed substantial evidence that fact indoctrination as a goal of teaching can no longer be justified since facts that are not related to principles are not retained to a very great degree. Educators must now shift their emphasis from the teaching of facts only to the teaching of facts as applying to scientific principles to be used in solving new problematic situations.

THE PROBLEM OF THIS INVESTIGATION

This investigation is undertaken to determine what principles of physical science have applications found in the seven industries of Littleton, Massachusetts. The list of 103 principles of physical science found by Miles to be essential and desirable for inclusion in an integrated course of physical science for the senior high school is used in this study. Applications of these 103 principles compiled for each of the seven Littleton industries are assigned to one or more principles and then a specialist in the teaching of science checked these assignments to determine if each

such application is an application of the principle to which it was assigned. The applications retained are then listed in descending order of their recurrence in the seven industries to determine the relative importance of the principle which they represent. It is further undertaken in this investigation to discover which physical science principles are taught in grades VII - XII, inclusive, of the Littleton Public School, a consolidated school of twelve grades with 270 pupils enrolled in grades VII - XII. The course offerings in science are: general science, grades VII and VIII; biology, grade X; chemistry and physics, alternate years, grades XI and XII. The results of this investigation should help the school to make better use of community resources and to develop in the pupils a better understanding of the principles of physical science.

STATEMENT OF THE PROBLEM

This investigation is made to determine the number of 103 principles of physical science, considered by a majority of a group of specialists in the teaching of science to be essential for inclusion in an integrated course of physical science for the senior high school, which are developed in whole or in part in grades VII - XII, inclusive, of the Littleton (Massachusetts) Public School; and to determine the applications of these 103 principles of physical science found in the industries of Littleton, Massachusetts.

SCOPE AND LIMITATIONS OF THE INVESTIGATION

In considering the relationship of physical science to industry, it is proposed to provide a more intelligent citizen in the community with respect to local industry, and not to over emphasize the vocational aspect.

Local industry has been considered as that industry which may be found within the territorial limits of the town of Littleton, Massachusetts.

The term industry may be defined as that activity which is required and involved in the transforming of raw material into a finished product.

Only the list of 103 principles of physical science considered by a majority of a group of specialists in the teaching of science to be essential for inclusion in an integrated course of physical science for the senior high school will be used in this investigation, and only the applications found in the seven industries of Littleton will be assigned to these principles.

CHAPTER II

RESEARCH

STATEMENT OF THE PROBLEM

The purpose of this part of the investigation was to determine the number of 103 principles of physical science, considered by a majority of a group of specialists in the teaching of science to be essential for inclusion in an integrated course of physical science for the senior high school, which are developed in whole or in part in grades VII - XII, inclusive, of the Littleton (Massachusetts) Public School.

TECHNIQUE EMPLOYED

A complete list of Wise's 272 physical science principles was presented to each science teacher, grades VII - XII, inclusive, of the Littleton Public School with these instructions;

I. This is a survey of grades VII - XII, inclusive to discover;

   A. The principles of physical science which are developed in whole or in part in the Littleton Public School, and

   B. The grade levels at which these principles of physical science are presented to the pupils.

II. Each physical science principle is identified with the field of science to which it belongs, by a letter: C-chemistry; P-physics; or L-geology.

III. In the column to the right of the principle, write the number of the grade or grades in which the principle is developed in whole or in part.

IV. If the principle is not taught by you, do not insert a grade number.

Two weeks later, these marked lists were collected from the teachers, and the results were tabulated for the 103 principles of physical science considered by a majority of a group of specialists in the teaching of science to be essential for inclusion in an integrated course of physical science for the senior high school. It is hereafter assumed that the 103 principles of physical science for such a course at the senior-high-school level would also include all principles of physical science appropriate for a lower grade level.

The course offerings in science are: general science, grades VII - VIII; biology, grade X; chemistry and physics, alternate years, grades XI - XII.

The following table shows which of the 103 principles of physical science the science instructors in the Littleton Public School thought they developed in whole or in part at designated grade levels.

TABLE I

PRINCIPLES OF PHYSICAL SCIENCE DEVELOPED IN WHOLE OR IN PART AT DESIGNATED GRADE LEVELS IN THE LITTLETON, MASSACHUSETTS PUBLIC SCHOOL

Principle	Grade 7	Grade 8	Grade 10	Grade 11	Grade 12	Total
PHYSICS						
1. *Energy can never be created or destroyed (except in nuclear physics); it can be changed from one form to another with exact equivalence.......		x	x	x	x	4
2. A gas always tends to expand throughout the whole space available.			x	x	x	3
3. When there is a gain in mechanical advantage by using a simple machine, there is a loss in speed and _vice versa_..............................			x	x	x	3
4. In the lever the force times its distance from the fulcrum equals the weight times its distance from the fulcrum...........................		x	x	x	x	4
5. The work obtained from a simple machine is always equal to the work put into it less the work expended in overcoming friction...............			x	x	x	3
6. Sound is produced by vibrating matter and is transmitted by matter..		x	x	x	x	4
7. Solids are liquefied and liquids are vaporized by heat; the amount of heat used in this process, for a given mass and a given substance, is specific and equals that given off in the reverse process...............	x	x	x	x	x	5

*Table I is read thus: the principle "Energy can never be created or destroyed;..." was considered to be developed in whole or in part in science courses offered in grades 8, 10, 11 and 12, a total of 4 different grades, by the science instructors of the respective grades.

TABLE I (CONTINUED)

Principle	Grade 7	8	10	11	12	Total
8. Most bodies expand on heating and contract on cooling; the amount of change depending upon the change in temperature........................	x	x	x	x	x	5
9. Heat is liberated when a gas is compressed, and is absorbed when a gas expands........................			x	x	x	3
10. The atmospheric pressure decreases as the altitude increases....	x		x	x	x	4
11. The higher the temperature of the air, the greater is the amount of moisture required to saturate it.....		x	x	x	x	4
12. Bodies of land heat up and cool off more rapidly than bodies of water.	x		x	x	x	4
13. The principal cause of wind and weather changes is the unequal heating of different portions of the earth's surface by the sun; thus all winds are convection currents caused by unequal heating of different portions of the earth's atmosphere, and they blow from places of higher atmospheric pressure to places of lower atmospheric pressure.................	x	x	x	x	x	5
14. If a beam of light falls upon an irregular surface, the rays of light are scattered in all directions......		x	x	x	x	4
15. Dark, rough or unpolished surfaces absorb or radiate energy more effectively than light, smooth or polished surfaces...................			x	x	x	3
16. The colors of objects depend upon what light rays they transmit, absorb or reflect.........................			x	x	x	3
17. Light travels in straight lines in a medium of uniform optical density.............................		x	x	x	x	4

TABLE I (CONTINUED)

Principle	Grade 7	8	10	11	12	Total
18. Waves travel in straight lines while passing through a homogeneous or uniform medium....................				x	x	2
19. When light is reflected, the angle of incidence is equal to the angle of reflection...................				x	x	2
20. Like electrical charges repel and unlike electrical charges attract....			x	x	x	3
21. A magnet always has two poles and is surrounded by a field of force....				x	x	2
22. Like magnetic poles always repel each other and unlike magnetic poles always attract each other............		x	x	x	x	4
23. Pieces of iron, steel, cobalt or nickel may become magnetized by induction when placed within a magnetic field.............................			x	x	x	3
24. An electric current may be produced in three ways: by rubbing or friction, chemical action, and the use of a magnetic field..............			x	x	x	3
25. An electric current will flow in the external circuit when two metals of unlike chemical activity are acted upon by a conducting solution, the more active metal being charged negatively...........................				x	x	2
26. An electromotive force is induced in a circuit whenever there is a change in the number of the lines of magnetic force passing through the circuit............................			x	x	x	3
27. A fluid (liquid or gas) has a tendency to move from a region of higher pressure to one of lower pressure; the greater the difference, the faster the movement......................		x	x			2

TABLE I (CONTINUED)

Principle	Grade 7	Grade 8	Grade 10	Grade 11	Grade 12	Total
28. Any two bodies attract one another with a force which is directly proportional to the attracting masses and inversely proportional to the square of the distance between their centers of mass......................		x	x	x	x	4
29. Movements of all bodies in the solar system are due to gravitational attraction and inertia............	x	x	x	x	x	5
30. The pressure in a fluid (liquid or gas) in the open is equal to the weight of the fluid above a unit area including the point at which the pressure is taken; it therefore varies as to the depth and average density of the fluid.....................				x	x	2
31. Bodies in rotation tend to fly out in a straight line which is tangent to the arc of rotation..........			x	x	x	3
32. A body immersed or floating in a fluid is buoyed up by a force equal to the weight of the fluid displaced................................		x	x	x	x	4
33. The pressure at a point in any fluid (liquid or gas) is the same in all directions......................			x	x	x	3
34. Heat is conducted by the transfer of kinetic energy from molecule to molecule..........................		x	x	x	x	4
35. When two bodies of different temperature are in contact, there is a continuous transference of heat energy from the body of higher temperature to the one of lower temperature, the rate of which is directly proportional to the difference of temperature..............			x			1

TABLE I (CONTINUED)

Principle	Grade					Total
	7	8	10	11	12	
36. The lower the temperature of a body, the less the amount of energy it radiates; the higher the temperature, the greater is the amount of energy radiated....................	x		x	x	x	4
37. Heat is transferred by convection in currents of gases or liquids the rate of transfer decreasing with an increase in the viscosity of the circulating fluid..................		x	x	x	x	4
38. Every pure liquid has its own specific boiling and freezing point..	x	x	x	x	x	5
39. The higher the pitch of a note, the more rapid the vibrations of the producing body and _vice versa_........			x	x	x	3
40. Musical tones are produced when a vibrating body sends out regular vibrations to the ear while only noises are produced when the vibrating body sends out irregular vibrations to the ear................................		x	x	x	x	4
41. Energy is often transmitted in the form of waves..................			x	x	x	3
42. When waves strike an object, they may either be absorbed, transmitted, or reflected.......................		x	x	x	x	4
43. When light rays are absorbed, some of the light energy is transformed into heat energy.............			x	x	x	3
44. The darker the color of a surface, the better it absorbs light..........	x		x	x	x	4
45. The intensity of illumination decreases as the square of the distance from a point source.................			x	x	x	3

TABLE I (CONTINUED)

Principle	Grade 7	8	10	11	12	Total
46. Radiant energy travels in waves along straight lines; its intensity at any distance from a point source is inversely proportional to the square of the distance from the source..........................			x	x	x	3
47. When light rays pass obliquely from a rare to a more dense medium, they are bent or refracted toward the normal and when they pass obliquely from a dense to a rarer medium, they are bent away from the normal..........................		x	x	x	x	4
48. An image appears to be as far back of a plane mirror as the object is in front of the mirror and is reversed..........................				x	x	2
49. Parallel light rays may be converged or focused by convex lenses or concave mirrors; diverged by concave lenses or convex mirrors........		x	x	x	x	4
50. Protons and neutrons only are found in the nucleus of an atom......			x	x	x	3
51. In an uncharged body there are as many protons as electrons and the charges neutralize each other while a deficiency of electrons produces a plus charge on a body and an excess of electrons produces a negative charge..........................				x	x	2
52. An electrical charge in motion produces a magnetic field about the conductor, its direction being tangential to any circle drawn about the conductor in a plane perpendicular to it..........................			x	x	x	3

TABLE I (CONTINUED)

Principle	Grade 7	8	10	11	12	Total
53. All materials offer some resistance to the flow of electric current, and that part of the electrical energy used in overcoming this resistance is transformed into heat energy..........................			x	x	x	3
54. The resistance of a metallic conductor depends on the kind of material from which the conductor is made, varies directly with the length, inversely with the cross sectional area, and increases as the temperature increases......................				x	x	2
55. The electrical current flowing in a conductor is directly proportional to the potential difference and inversely proportional to the resistance.............................			x	x	x	3
56. Electrical power is directly proportional to the product of the potential difference and the current...				x	x	2
57. When a current-carrying wire is placed in a magnetic field, there is a force acting on the wire tending to push it at right angles to the direction of the lines of force between the magnetic poles, providing the wire is not parallel to the field....				x	x	2
58. The atoms of all radioactive elements are constantly disintegrating by giving off various rays (alpha, beta, and gamma) and forming helium and other elements.................				x	x	2
59. The energy which a body possesses on account of its position or form is called potential energy and is measured by the work that was done in order to bring it into the specified condition............................		x	x	x	x	4

TABLE I (CONTINUED)

Principle	Grade 7	8	10	11	12	Total
60. When the resultant of all the forces acting on a body is zero, the body will stay at rest if at rest, or it will keep in uniform motion in a straight line if it is in motion.....			x	x	x	3
61. When one body exerts a force on a second body, the second body exerts an equal and oposite force on the first..............................			x	x	x	3
62. When pressure is applied to any area of a fluid (liquid or gas) in a closed container, it is transmitted in exactly the same intensity to every area of the container in contact with the fluid.........................			x	x	x	3
63. The average speed of molecules increases with the temperature and pressure; conversely, the temperature and pressure increase as the average speed of molecules increases and decrease as the average speed of molecules decreases.................			x	x	x	3
64. Condensation will occur when a vapor is at its saturation point if centers of condensation are available and if heat is withdrawn........			x	x	x	3
65. A change in state of a substance from gas to liquid, liquid to solid, or _vice versa_, or from solid to gas or _vice versa_, is usually accompanied by a change in volume..........			x	x	x	3
66. The presence of a non-volatile substance will cause the resulting solution to boil at a higher temperature and to freeze at a lower temperature than pure water..........			x	x	x	3

TABLE I (CONTINUED)

Principle	Grade 7	8	10	11	12	Total
67. The volume of an ideal gas varies inversely with the pressure upon it, providing the temperature remains constant...........................			x	x	x	3
68. Whenever an opaque object intercepts radiant energy traveling in a particular direction, a shadow is cast behind the object..............			x	x	x	3
69. The dispersion of white light into a spectrum by a prism is caused by unequal refraction of the different wave lengths of light.........		x	x	x	x	4
70. Positively charged ions of metals may be deposited on the cathode, as atoms, when a direct current is sent through an electrolyte..............			x	x	x	3
71. In a transformer the ratio between voltages is the same as that between the number of turns..........				x	x	2
72. Energy in kilowatt hours is equal to the product of amperes, volts, and time (in hours) divided by one thousand...........................		x		x	x	3
73. The mass of an atom is concentrated almost entirely in the nucleus............................				x	x	2
CHEMISTRY						
74. Elements are made up of small particles of matter called atoms which are alike in the same element (except for occasional differences in atomic weight; i.e., isotopes) but different in different elements..			x	x	x	3

TABLE I (CONTINUED)

Principle	Grade 7	8	10	11	12	Total
75. All substances are made up of small particles called molecules which are alike in the same substance (except for variations in molecular weight due to isotopes) but different in different substances...........................			x	x	x	3
76. All matter is composed of single elements or combinations of several elements and can be analyzed by chemical processes and divided into these constituents.......................		x	x	x	x	4
77. Every pure sample of any substance, whether simple or compound, under the same conditions will show the same physical properties and the same chemical behavior...............			x	x	x	3
78. The materials forming one or more substances, without ceasing to exist, may be changed into one or more new and measurably different substances..			x	x	x	3
79. Oxidation always involves the removal or sharing of electrons from the element oxidized while the reduction always adds or shares with the element reduced...................				x	x	2
80. Oxidation and reduction occur simultaneously and are quantitively equal................................			x	x	x	3
81. The exchange of the negative and positive ions of acids and bases results in the formation of water and a salt...........................				x	x	2
82. Electrolytes dissolved in water exist partially or completely as electrically charged particles called ions............................				x	x	2
83. All matter is made up of protons, neutrons and electrons...............			x	x	x	3

TABLE I (CONTINUED)

Principle	Grade 7	8	10	11	12	Total
84. The electrons within an atom form shells about the nucleus, each of which contains a definite number of electrons..........................				x	x	2
85. The solubility of solutes is affected by heat, pressure, and the nature of the solute and solvent.....				x	x	2
86. The valence of an atom is determined by the number of electrons it gains, loses or shares in chemical reactions.........................				x	x	2
87. Most atoms have the property of losing, gaining, or sharing a number of out shell electrons...............				x	x	2
88. The energy shown by atoms in completing their outer shell by adding, losing or sharing electrons determines their chemical activity........				x	x	2
89. The properties of the elements show periodic variations with their atomic numbers......................				x	x	2
90. Each combustible substance has a kindling temperature which varies with its condition but may be greater or less than the kindling temperature of some other substance..............	x	x	x	x	x	5
91. Matter may be transformed into energy and energy into matter; the sum total, matter plus energy, remains constant.......................			x	x	x	3
92. The total mass of a quantity of matter is not altered by any chemical or physical changes occurring among the materials composing it...........			x	x	x	3
93. The rates of many reactions are affected by the presence of substances which do not enter into the completed chemical reaction..........			x	x	x	3

TABLE I (CONTINUED)

Principle	Grade 7	8	10	11	12	Total
94. Acids and bases in water solution ionize to give hydrogen and hydroxyl ions, respectively, from their constituent elements....................				x	x	2
95. The ingredients of a solution are homogeneously distributed through each other.........................				x	x	2
96. When different amounts of one element are found in combination with a fixed weight of another element (in a series of compounds) the different weights of the first element are related to each other by ratios which may be expressed by small whole numbers..............................				x	x	2
97. Atoms of all elements are made up of protons, neutrons, and electrons, and differences between atoms of different elements are due to the number of protons and neutrons in the nucleus and to the configuration of electrons surrounding the nucleus.............			x	x	x	3
GEOLOGY						
98. When elevations or depressions are created upon the surface of the earth, the elevations are usually attacked by the agents of erosion, and the materials are carried to the depressions.......................			x			1
99. Streams, generally, are lowering the surface land in some places and building it up in other places.......	x		x			2
100. Rocks may be formed by the compacting and cementing of sediments...	x		x			2
101. The earth's surface may be elevated or lowered by interior forces..			x	x	x	3

TABLE I (CONCLUDED)

Principle	Grade					Total
	7	8	10	11	12	
102. Strata of rocks occur in the earth's crust in the order in which they were deposited, except in the case of overthrust faults...........						
103. Earthquakes are produced by the sudden slipping of earth materials along faults........................						

Findings Table I. A total of 103 principles of physical science, 73 of physics, 25 of chemistry, and 6 of geology, was considered by the science instructors to be developed in whole or in part on at least one grade level from grades VII - XII, inclusive. Of the total of 103 different principles, not one was developed in whole or in part in all six grades, 6 were developed in five different grades, 22 in four grades, 43 in three grades, 28 in two grades and 4 in only one grade. Thus, repetition of attempts to develop a principle at increasingly higher grade levels is properly shown.

The number of different principles taught at different grade levels were: grade VII, 12; grade VIII, 26; grade IX, 0; grade X, 77; grade XI, 96; and grade XII, 96. This indicates an attempt to develop an understanding of an increasingly greater number of principles at successively higher grade levels.

Seventy-one of the 103 principles were first introduced at the senior-high-school level, grade X or later. Thirty-two of the principles were first introduced at the junior-high-school level, twelve in grade VII and twenty in grade VIII.

CHAPTER III

RESEARCH

STATEMENT OF THE PROBLEM

In this part of the investigation, the purpose was to determine the applications of the 103 principles of physical science found in the industries of Littleton, Massachusetts.

TECHNIQUE EMPLOYED

The list of 103 principles of physical science considered by a majority of a group of specialists in the teaching of science to be essential for inclusion in an integrated course of physical science for the senior high school were transcribed individually on a sheet of loose-leaf notebook paper, eight by eleven inches.

Method of Obtaining Applications of Principles in Industries

The different industries in the order visited with name of industry and items produced were: (1) Woodworking Factory, interior upholstery forms; (2) Iron Works, conveyors; (3) Box Factory and Lumber Mill, finished wooden boxes, and lumber; (4) Woodworking Factory, radio receiver cabinets; (5) McElroy Automatic Telegraph Equipment, electric automatic telegraph recording and transmitting equipment; (6) The

United Elastic Corporation Factory, elastic webbing; and (7) The Nashoba Vinegar Works, vinegar, cider, jelly, and prune and apple juices. Each factory was entered, permission to visit was procured, and each process was noted by observation, questioning of individuals working on the process, and questioning of the plant manager concerning the process. Finally, each process was visited a second time in order to obtain applications that were not found on the first visit. Each application of a principle found by general observation within a factory or by observation of definite processes was allocated by the investigator to the principle or principles which in his opinion the application represented.

The criteria for selecting an application were obtained from Wise's[1] study: An application shall be considered to be a suitable one if, in the opinion of the investigator, it

A. Represents a problematic situation involving in its solution an understanding of one or more of the principles of physical science:
B. Suggests information which in itself would be of practical value in daily life apart from vocational or professional interests, or which would possess cultural value to the average citizen apart from practical value.

However, for the purposes of this part of the investigation dealing with the applications of science in a small local community, each factory was assumed to "possess cultural value to the average citizen apart from practical value."

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[1]Harold W. Wise, "A Determination of the Relative Importance of Principles of Physical Science for General Education," Science Education, XXV (December, 1941), 372.

The applications pertaining to any one entire industry were noted with one special color of ink, and if the principle employed the same application in more than one industry, one or more columns in a series of six columns pertaining to each additional industry was checked in ink of a different color to show the repetition of that application. The applications thus obtained were arranged in descending order of their frequency of recurrence in the seven industries of Littleton, Massachusetts.

Coefficient of Reliability for the Assignment of Applications to Principles

The coefficient of reliability for the assignment of applications to principles is for the purposes of this investigation defined as the quotient obtained by dividing the number of assignments common to two different assignments of applications to principles by the total number of different assignments made by twice assigning the same applications to principles. Fifty applications of one process in a industry were assigned at two different times three months apart by the investigator to principles which the applications represented. The method of obtaining the coefficient of reliability is a modification of that used by Wise[2]. It was found that the coefficient of reliability of the investigator's

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[2]Harold W. Wise, A Determination of the Relative Importance of Principles of Physical Science for General Education, pp. 68-70. Unpublished Doctor's dissertation, University of Michigan, 1941.

judgment in the assignment of applications to principles was 0.88.

Validation of the Assignment of Applications to Principles

The assignment of applications to principles was validated by the following procedure. A tentative list of 1296 different assignments of applications from the seven industries of Littleton, Massachusetts was assigned by the investigator to ninety principles of physical science. This list was then presented to a specialist in the teaching of science who was instructed to delete from the list of applications under each principle any application not considered by him to represent that principle, and to indicate additional assignments or reassignments of individual applications to one or more principles or the appendix. Thus, all applications were deemed to be validly assigned to the principles under which they were finally listed.

The following table shows the applications of the principles of physical science found in seven industries of Littleton, Massachusetts arranged under the principles of physics, chemistry, and geology in descending order of their frequency of recurrence in different industries.

TABLE II

APPLICATIONS OF THE ONE HUNDRED THREE PRINCIPLES OF PHYSICAL SCIENCE FOUND IN SEVEN INDUSTRIES OF LITTLETON, MASSACHUSETTS ARRANGED UNDER THE PRINCIPLES OF PHYSICS, CHEMISTRY, AND GEOLOGY IN THE DESCENDING ORDER OF THEIR FREQUENCY OF RECURRENCE IN DIFFERENT INDUSTRIES

Principle and Applications	Number of Different Industries
PHYSICS	
1. Energy can never be created or destroyed (except in nuclear physics); it can be changed from one form to another with exact equivalence.	
*How the window lights the room, and tends to warm it......................................	7
When electrical energy is transferred to mechanical energy of sawing...........................	6
How the body supplies chemical energy to do mechanical work................................	6
How the incandescent bulb works to change electrical energy to light and heat energy........	6
How electrical energy is transferred into mechanical energy of machinery.....................	6
When mechanical energy of drilling, sawing, hammering, chiselling is turned into heat energy by friction..................................	6
When mechanical energy is supplied to lift bundles of wood................................	5
When bundles of wood are dropped and pieces of wood are thrown into piles...................	5
How current and a gas produce illumination flourescently....................................	5
How heat is also produced by sunlight on the painted surfaces...............................	4
Why the temperature inside a building is warmer than the outdoor air........................	4
When electrical energy is changed into heat energy in arc welding...........................	3
How heat is changed to chemical energy for drying paint...	2
How electricity is used to turn motors to run machinery.......................................	2

*Table II is read thus: The principle, "Energy can never be created or destroyed..." has the application, "How the window lights...", in each of seven industries.

TABLE II (CONTINUED)

Principle and Applications	Number of Different Industries
How mechanical energy sprays oil into the furnace which produces chemical energy by burning, and is then turned into light and heat energy.....	2
When coal is changed into heat energy for forging..	1
How mechanical energy is used to generate direct current..	1
How mechanical energy of the moving strands of yarn is turned into heat energy...............	1
How friction of the yarn turning produces a change of mechanical energy to electrical energy (static electricity)..................	1
How electrical energy is turned into mechanical energy for conveyor purposes..................	1
How heat energy of steam is turned into mechanical energy of pressure to pump tanks dry, or to pump tanks full...........................	1
How the chemical energy of coal is turned into heat for steam................................	1
How the chemical energy is turned into heat energy in solidification of jelly..................	1
Why the vinegar is allowed to work continuously to keep the heating element as high as possible..	1
Why logs dropping heavily tends to shake pieces of wood from piles..........................	1
2. A gas always tends to expand throughout the whole space available.	
Where oxygen and gases are diffused into the air for men to breathe..........................	7
When the evaporation of moisture from the wood tends to permeate the room..................	5
Why fresh air is obtained through one window.....	5
Why the light is distributed equally in a flourescent bulb..................................	5
When the smell of the arc welder permeated the entire room when in the process of cutting through metals..............................	3
Why small particles act as light as air and tend to move throughout the room..................	3
Why paint confined to one room is everywhere noted throughout that room..................	3
Why water vapor may be stronger within the limits of the paint room.........................	3

TABLE II (CONTINUED)

Principle and Applications	Number of Different Industries
Why smoke is found throughout a room..............	2
Why the smell of glue is also throughout the room.	2
Why steam expands to all space available..........	2
Why water vapor expands throughout the room to keep it correctly humidified...................	2
Why the bleach vats and dyeing vats tend to produce a vapor noticeable about the entire room..	2
Why vaporized oil of the machinery can be detected in the room............................	2
Why the smoke from the forge tends to permeate the room..................................	1
How vaporized kerosene tends to include all space avaiable in the furnace....................	1
How the smell of the different cooking solutions permeates the entire industry appetizingly.....	1
How the sulphur dioxide gas expands throughout the room..................................	1
How the smell of apples permeates the entire fridgidaire.................................	1
How the ammonia gas of refrigeration is noticed around the compressor units of the fridgidaire.	1
How acetic acid gas tends to escape and eat metal near vinegar tanks...........................	1
How oil particles tend to fill the entire furnace heating area................................	1
3. When there is a gain in mechanical advantage by using a simple machine, there is a loss in speed and *vice versa*.	
Why wheels are used in transferring blocks of wood from one machine to another....................	6
Why wrenches are used to turn bolts...............	6
When use of screw sacrifices distance for gain in effort....................................	6
How a lathe is adjusted by a worm gear............	6
How the machine tools are held together in working to provide speed at the cost of mechanical advantage................................	6
When the speed of a descending hammer traveling a few feet has the ability of only being able to push....................................	6
How clamps are used to hold pieces of metals in place...................................	4
How a metal machine saw is adjusted...............	3
How a thread is run by a die on raw stock.........	3

TABLE II (CONTINUED)

Principle and Applications	Number of Different Industries
Why the pulley and chain is used to lift the stored stock....................................	3
How cartons are unloaded from trucks..............	2
How ramps are used to wheel stock to lower or higher surfaces...............................	2
When a cantdog is used to move a log..............	1
How logs are pried from a truck by a board........	1
How a belt sander scrapes wood slowly.............	1
How different parts of the winding and weaving machines are used in different processes.......	1
How an elevator obtains its power.................	1
How large spools are lifted to carriers...........	1
How smallspools are used and detached from machines..	1
How elastic ribbon is inspected and packed........	1
How the machines wind yarn around the rubber......	1
How additional liquid is automatically put into the dye or bleach bath..........................	1
How rubber is stranded and combed.................	1
How apples are directed into chutes by an inclined plane...................................	1
How tieing ends are tending to use the fingers as levers....................................	1
How hydraulic energy is used to press apples......	1
How conveyor belts move apples, jars, mash from place to place..............................	1
How barrel staves are hammered to become tighter....................................	1
How barrels are picked up.........................	1
How apples are lifted to be graded and then placed individually in peeling machines........	1
How apples are peeled, sliced, and shovelled by scoop into buckets..........................	1
How boxes of bottles are packed and unpacked......	1
How wheel barrows are used to empty cylinders of prunes..	1
How heavy rolls of twist are lifted from the floor by block and pulley......................	1
How spools are picked up by hand, or by winch.....	1
4. In the lever the force times its distance from the fulcrum equals the weight times its distance from the fulcrum.	
How the hammer works when you pull a nail.........	6
When the arm and hammer is used to drive nails....	6

TABLE II (CONTINUED)

Principle and Applications	Number of Different Industries
When the sliding doors are open..................	6
How the stove door is opened.....................	6
When the platform is wheeled out.................	6
How the raw stock is unloaded by hand, or hand truck....................................	6
How machines (drills, lathes) are adjusted to do work.....................................	6
How the doors are fastened.......................	6
How the heavier stock is shifted into position...	6
How the stock is held against the grinding wheel and other instruments........................	6
How a board is picked up.........................	5
When a wrench is used to turn bolts or nuts......	5
How the jaws of a vice work......................	4
How a die is turned..............................	4
How metal stock is lifted from place to place....	4
How a piece of metal is fitted and bent into place....................................	4
How the work is lined up to be bolted............	4
How the platforms of boxes are lifted and shifted..................................	4
How boxes are picked up into the arms............	4
How boards are sawed for correct lengths.........	4
How pieces of material are prepared for painting.................................	4
How the nailing machines hammer the nails into the wood................................	2
How stencils are cut.............................	2
How boards break off the log.....................	2
How boards are resawed..........................	2
How pieces are bent and glued onto one another...	2
How raw material and finished products are weighed..................................	2
How materials are transferred from floor to floor	2
When the conveyor is used to balance the tools and materials on saw-horses.................	1
How logs are lifted onto the saw rig by peevie...	1
How logs are piled for reserve stock.............	1
When materials are fitted into patterns by hand..	1
When leatherette is used to cover wood forms.....	1
How finished cabinets are stacked................	1
How spools are picked-up, by hand, or winch......	1
How the bobbins are compelled through the loom in weaving..................................	1
How electrical contacts of broken thread ends opens the circuit...........................	1

TABLE II (CONTINUED)

Principle and Applications	Number of Different Industries
How rolls of finished webbing are picked-up, packed and graded..............................	1
How pressure is maintained on the stretched yarn and elastic for weaving and rolling of webbing....................................	1
How the winch is used for moving heavy rolled twist......................	1
How the scissors work in cutting webbing.........	1
How the wheelbarrow is used to transfer finished prunes....................................	1
How the shovel is used to shovel apple cores onto conveyors................................	1
How all raw stock is lifted and piled, and unpiled for use................................	1
How bottles, barrels and tubs are lifted into storage after being filled..................	1
5. The work obtained from a simple machine is always equal to the work put into it less the work expended in overcoming friction.	
Why the saw has made use of the wheel and axle to saw wood................................	6
When a screw is used as a wedge..................	6
When a cold chisel is used to shear off corners of stock....................................	6
How a wrench is used to tighten bolts and nuts...	6
How a lathe work is grooved and trimmed..........	6
Why block and pulley is used to lift heavy weights...................................	6
When axle and wheel are used to move bundles and slabs of wood...............................	5
When axle and wheel is used to move the saw platform for trimming..........................	5
How a vise works.................................	5
How the hammer works in pounding a nail..........	5
Why a drill planes holes in metal................	4
How a saw works in cutting metal.................	4
Why the bundles of wood used are carried instead of being dragged.............................	4
How heavy boards are lifted by hand..............	4
How boxes are tossed into piles by hand..........	4
How cabinets or boxes are loaded on and off of trucks....................................	4
Why bolts are used to hold two surfaces of material together.............................	3

TABLE II (CONTINUED)

Principle and Applications	Number of Different Industries
How the wood stock is planed....................	3
How drafting tools are used.....................	3
How a stapler is used to staple.................	3
How dragging the boxes and shifting them about is a lever in action...........................	2
When the corners are rounded off, the box is held correctly by hand............................	2
How a metal die is used to cut threads..........	1
How peevies are used to roll logs...............	1
How the logs are thrown from the trucks.........	1
How boards are pushed through a resaw job.......	1
How glue press works by a simple screw..........	1
How leatherette is held down to cover wood in the glueing process............................	1
How the belt sander is used to sand a flat area..	1
How patterns are used in cutting out forms by hand...	1
How spools, cones, twist are placed on machinery by hand......................................	1
How woven webbing is kept taught and rolled......	1
How elastic is separated according to the number of ends.....................................	1
How the electrical contacts for shutting current off open if the end of yarn is broken.........	1
How elastic is covered..........................	1
How heavy spools are moved from place to place by a small truck................................	1
How a small winch is used to lift heavy twists to machinery.....................................	1
How webbing is packed...........................	1
How folded twist is rolled by hand..............	1
How shuttles are rethreaded.....................	1
How bleaching tub door is lifted................	1
How a machine is clutched into master drive......	1
How flat boxes are lifted to be put together.....	1
How the scale works for weighing materials in and out of factory................................	1
How the doors are opened and closed by hand......	1
How ends are tied together for correct number of strands for spooling..........................	1
How the jars of vinegar are lifted for testing...	1
How the filtering forms are held in a vise.......	1
How pearings are shovelled onto conveyor lines...	1
How wheelbarrows are used to cart away finished prunes.......................................	1

TABLE II (CONTINUED)

Principle and Applications	Number of Different Industries
How the bottles are filled to a correct depth by a lever arm..................................	1
How cider is pressed out hydraulically..........	1
How a wedge is used to hammer hoops around barrel staves..................................	1
How cut apples are dolled out by lever and fulcrum..................................	1
How products are stored, lifted to machinery or disposed by hand...........................	1
6. Sound is produced by vibrating matter and is transmitted by matter.	
When the doors are open while materials are being brought in or carried out.....................	6
When the sound is heard from the squeak of the wheels running on the floor..................	6
Why all moving parts of machinery tend to make noise that can be heard.....................	6
How the saw sounds when vibrating through wood and metal...............................	6
Why the grinder's movement is felt through the floor and woodwork........................	6
Why the lathe vibrating on its wooden floor is heard in other parts of the shop.............	6
When the door slams the vibration is heard and is felt as it makes the building shudder........	6
When the hammer hits a nail.....................	5
How the wood is pushed apart by the saw..........	5
When bundles of wood are dropped into receptacles on the floor..............................	5
When one board is dragged across another.........	5
How the drill is heard and the vibration is felt when it goes into a piece of stock...........	4
When the hammer strikes a bolt..................	3
When the vibration of the nailing machines are felt all around the floor of the room.........	2
Why different departments are departmentalized, and compartmentalized to subdue excessive noise..................................	2
When logs roll off their sawing carriers, the noise is heard throughout the building........	1
How each strand of yarn makes a sound if stretched when the machinery is in action around it..	1

TABLE II (CONTINUED)

Principle and Applications	Number of Different Industries
How each part of a loom in action tends to have a regular vibration, but together they make noise because of a difference of pitch........	1
Why there seems to be an ominous silence when a machine stops running and the building becomes quieter.....................................	1
How the sound from the conveyor causes the jars to vibrate together so that they have to be guarded against breaking.....................	1
Why the turnings inside a wood shop can be heard from the exterior of the shop.................	1
7. Solids are liquefied and liquids are vaporized by heat; the amount of heat used in this process, for a given mass and a given substance is specific and equals that given off in the reverse process.	
When moisture is vaporized by heat of sawing.....	5
When the sun and air dries wood, or the heater dries wood..................................	5
When glue dries..............................	4
When iron is soldered........................	4
Why it takes different amounts of heat to melt different metals..............................	4
When iron is welded..........................	3
Why glue hardens in the pot and requires heat to thin it....................................	3
When air is humidified.......................	2
When steam is produced.......................	2
When paint dries.............................	1
When theoil fire is used to heat water for steam.	1
How steam is used to boil concentrate...........	1
How steam is used to cook prunes.................	1
How steam is used to cook jell...................	1
Why steam tends to pasteurize apple juice........	1
How the worms in vinegar cylinders help vaporize hard cider into vinegar by heat...............	1
How more refrigeration is needed to cool off liquids while solids cool off more rapidly......	1
How water soaks up heat to melt ice.............	1
How fire produces steam and pressure............	1

TABLE II (CONTINUED)

Principle and Applications	Number of Different Industries
8. Most bodies expand on heating and contract on cooling; the amount of change depending upon the change in temperature.	
When the stove heats up..........................	6
Why the saw begins to bind when heated...........	6
Why motors run better after they are warmed up...	6
When the grinder is used on metal stock, the stock is heated and expands.........................	6
How the drill binds..............................	5
Why metals are allowed space for expansion when fitted together................................	4
How bearings are helped to be held in place on a bearing arm......................................	4
Why micrometers are used on stock to measure it after it is cooled............................	3
When the arc welder is used to weld objects together....................................	3
Why forged articles are cooled quickly to temper them.....................................	1
When the large log is cut by the logging saw, the groove is wider after the saw is heated to running temperature............................	1
How all the machinery of weaving has to be the correct temperature and the correct humidity has to be present to maintain the yarn at the correct weaving temperature..................	1
Why the sprinkler system is filled with air to prevent it from freezing at lower temperatures.	1
How the oil is forced into the boiler under pressure.................................	1
Why heating or cooling of glass has to be done gradually to prevent breakage.................	1
Why temperature has to be safeguarded to prevent excessive expansion of cooking vats...........	1
Why the hot steam reaches all areas and is used to sterilize receptacles.....................	1
9. Heat is liberated when a gas is compressed and is absorbed when a gas expands.	
How the frigidaire cools off its contents........	3
How the compression of the bleach solution tends to make machinery and container warmer........	1
How the humidifier works and produces a steam-jet which makes the nozzle cold.............	1

TABLE II (CONTINUED)

Principle and Applications	Number of Different Industries
How heat furnished by steam helps heat cooking tanks when the steam is compressed...........	1
How sulphur dioxide gas makes the water cooler when it is expanded to normal pressure directly from the storage bottle......................	1
How compressed steam is used to pump hot liquids about...	1
10. The atmospheric pressure decreases as the altitude increases.	
11. The higher the temperature of the air, the greater is the amount of moisture required to saturate it.	
Why the men perspire over their work at times, but not at other times........................	6
Why the workmen are cold and wear heavy clothes..	6
How the equipment seems to rust faster in a colder room, providing the temperature is lowered..	5
Why the room is kept much more warmer to facilitate drying of paint..........................	3
Why the water tends to keep the air cool around the buildings..............................	1
How the moisture in the paint chamber helps to diffuse paint...............................	1
Why the air needs to be humidified automatically to keep the yarn at its best weaving temperature......................................	1
Why the drying room has direct ventilation.......	1
How webbing is dried at a certain rate to make it a continual process with the aid of steam.....	1
How so much of the steam diffuses in air, and condenses around the cold pipes...............	1
How condensation takes place around the entrance to deep freeze.............................	1
How in the colder vinegar department, the air is less saturated than it is above the warm vinegar tanks..............................	1
How heat is blown by fans to help absorb moisture from the newly washed canning machinery.......	1
Why an apple shrinks after storage..............	1

TABLE II (CONTINUED)

Principle and Applications	Number of Different Industries
12. Bodies of land heat up and cool off more rapidly than bodies of water.	
Why water near a building tends to cool the building even when it is heated by the sun's radiation....................................	1
How more refrigeration is needed to cool off liquids while solids cool off more rapidly......	1
13. The principle cause of wind and weather changes is the unequal heating of different portions of the earth's surface by the sun; thus all winds are convection currents caused by unequal heating of different portions of the earth's atmosphere, and they blow from places of higher atmospheric pressure to places of lower atmospheric pressure.	
14. If a beam of light falls upon an irregular surface, the rays of light are scattered in all directions.	
When the light from the windows reaches a point on the floor and is diffused to furnish light to see the work by.............................	7
How an electric light bulb lights up a room......	7
When light hits the side of a saw blade..........	6
When light hits the clean, rough boards..........	5
Why the sawdust pile appears brighter............	5
When the light falls on the smooth surface of a machine there seems to be glare...............	5
Why the interior of the room seems to be boarded up with a light smooth composite material for better reflection.............................	5
When light hits the finely ground particles of sawdust on the benches and walls, a greater amount of light appears to be reflected.......	5
Why light appears to glisten more intensively from a ground piece of stock than from a piece not ground.................................	4
Why the different lathe cuttings appear to glisten even more than the original stock.....	4
Why iron filings appear to reflect more light than does a smooth piece of iron..............	4

TABLE II (CONTINUED)

Principle and Applications	Number of Different Industries
When light hits the rough finished boxes, less light is actually reflected directly, and more light is diffused than on a newly varnished box....................................	2
Why the top of bleaching solution tends to produce a glare..................................	2
Why certain parts of a loom tend to reflect light more brilliantly than other parts and tends to scatter light from points of light near the ceiling of the room.........................	1
Why the presence of white elastic in a box or room tends to illuminate the area around the box to a greater degree......................	1
Why the worn and highly polished parts of machinery and floor tend to reflect more direct light than normal machinery..................	1
Why liquid that is bleached provides a better transmission of light.........................	1
15. Dark, rough or unpolished surfaces absorb or radiate energy more effectively than light, smooth or polished surfaces.	
Why the stove has a rough surface to produce more heat..................................	6
When the teeth of saws bit into wood.............	6
How more light is reflected when stock is ground.	6
Why dark machinery needs more light to illuminate settings..............................	6
Why a white light reflector is used over flourescent lamps...............................	6
Why shafts of machinery are polished and oiled to keep friction and heat down................	6
Why gloves are used on hands to prevent blisters on heavy rough work.........................	6
Why the teeth of the drill radiate heat in drilling..	5
Why light is reflected more from new iron filings than from rusted stock.......................	4
Why a file radiates heat when in use............	4
Why grindings heats up metal quickly............	4
Why rough floors tend to produce more friction on boxes dragged over it.........................	4
Why dark clothes are worn to absorb more light and heat.....................................	4

TABLE II (CONTINUED)

Principle and Applications	Number of Different Industries
Why an opaque light glass is used to protect the eyes in arc welding..............................	3
Why planing tends to heat up a great deal the surface of the plane so that heat is transmitted..	3
How painted surfaces tend to make a product smoother......................................	3
Why heavy rough plates are put on ramp surfaces to increase friction..........................	2
Why course sandpaper belt tends to heat wood up faster when it is used in grinding............	1
Why leatherette covered boxes tend to protect wood surfaces and allow less friction when rolled over it by rollers.....................	1
How the rough elastic is covered to prevent friction of rough surfaces....................	1
Why rough yarn in motion tends to burn the hands more than the smooth rayon....................	1
Why rayon webbing is smoother and more comfortable for girdles....................................	1
How a dull blade causes more friction in cutting apples..	1
How utensils are kept clean to prevent sticking and burning of jelly on their surfaces........	1
16. The colors of objects depend upon what light rays they transmit, absorb, or reflect.	
When different colors are reflected or absorbed by machinery, iron plates, floors, and other colored surfaces in the room...................	7
Why different stocks have different colors and the colors appear to be a different shade in strong light...................................	6
Why light composition is used to reflect more light and make a place more cheery............	6
Why white is used to show up settings on machinery, blue prints, and drafting......................	6
Why wood tends to reflect more light than to absorb it with the bark off....................	4
Why dark clothes are worn to absorb more light and heat..	4
Why paint is applied to reflect only a certain color and absorb the rest.....................	4
Why the building is painted white to allow more reflection of light..........................	4

TABLE II (CONTINUED)

Principle and Applications	Number of Different Industries
Why raw lumber and sawdust have the same general reflecting qualities until weathered or covered	3
How stained wood fits more general settings than any kind of painted wood	2
Why certain colors have a brighter intensity in appearance than other colors	2
Why yarn is bleached so that all colors will be reflected	1
Why elastic is dyed pink in color so that it will have feminine appearance for women	1
Why dyed webbing reflects one certain color and absorbs the rest	1
Why white yarn is worked with to enable the workers to work faster, and see the strands better	1
Why jelly transmits the light of its ingredients	1
Why bleached vinegar transmits more light than regular vinegar	1
How prune juice absorbs more light and transmits less light than apple juice	1
How the shade of regular unbleached vinegar determines to some extent what amount of acetic acid is present	1
How apples are usually red, green or yellow	1
Why the building is painted white to allow more reflection of light	1
Why rubber is covered so that the surface may be dyed to reflect or absorb light as to color	1
When light is reflected from an aluminum painted van	1
When light is reflected from the elastic bleached cones and webbing	1
17. Light travels in straight lines in a medium of uniform optical density.	
When the light from windows reaches a point on the floor and is diffused to furnish light to see to work by	7
How an electric light bulb lights up a room	7
Why machinery tends to cast a direct shadow onto the floor	6
Why sunlight tends to beam itself through an opening	6

TABLE II (CONTINUED)

Principle and Applications	Number of Different Industries
Why with an intense arc shadows are produced by machinery in the room..........................	3
Why light waves seem to be beamed through a solution in straight lines....................	2
18. Waves travel in straight lines while passing through a homogeneous or uniform medium.	
When the light from the windows reaches a point on the floor and is diffused to furnish light to see by.................................	7
How an electric light bulb lights up a room......	7
Why machinery tends to cast a direct shadow onto the floor..................................	6
Why sunlight tends to beam itself through an opening....................................	6
Why a different sound seems to be heard through woodwork surrounding the machine than through the air, itself...........................	6
Why sound is heard outside of the building after being transmitted through walls...............	5
Why with an intense arc shadows are produced by machinery in the room.........................	3
Why light waves seem to be beamed through a solution in straight lines.....................	2
Why the sound of all the machinery can be heard through the building and tends to give an idea of the bustle going on within.................	2
How heat is radiated from all heated surfaces to adjacent material...........................	2
Why waves passing through a colored gauge tend to cast a colored shadow directly opposite to the gauge....................................	1
Why copper is used to transmit heat from steam to the solution of jelly and juices in straight lines....................................	1
19. When light is reflected, the angle of incidence is equal to the angle of reflection.	
When light is reflected from the machinery.......	7
How light diffuses at a certain angle for a particular job.................................	6

TABLE II (CONTINUED)

Principle and Applications	Number of Different Industries
When light strikes the floor, it is reflected at a direct angle....................................	6
Why a reflector is used to focus light in one direction....................................	6
Why light reflected off of shining tools seems to be bright and somewhat focused................	5
Why when holding stock at a certain angle, the ground edge appears shiny........................	4
Why light seems to be reflected to show brightness of cutting surfaces of tools.............	4
How light is reflected from the aluminum sander..	2
How polished canvas seems to reflect more light than regular canvas..........................	2
How boxes and cartons of light color reflect more light than the floor.........................	1
How the light is reflected from parts of the loom.	1
How light is reflected from the surface of a solution..	1
How light is reflected from light source to copper kettles to the eyes.......................	1
How light is reflected from glass bottles, empty or filled, to our eyes.......................	1
How light strikes pools of water on the floor and is reflected..................................	1
How light strikes hard surfaces of coal and makes them shine....................................	1
How reflection of light is obtained from crystalline substances in solution to determine amount of solids present in jelly, juice, or vinegar.	1
20. Like electrical charges repel and unlike electrical charges attract.	
Why ground wires are used to neutralize the static electricity built up when yarn is rubbing against machinery........................	1
21. A magnet always has two poles and is surrounded by a field of force.	
How a motor employs the use of electro-magnets...	7
How coils on transformers help step voltage up or down..	6

TABLE II (CONTINUED)

Principle and Applications	Number of Different Industries
22. Like magnetic poles always repel each other and unlike magnetic poles always attract each other.	
How a motor runs..................................	7
23. Pieces of iron, steel, cobalt or nickel may become magnetized by induction when placed within a magnetic field..	
How electromagnetic parts in motors work.........	7
Why iron filings tend to fall in a symmetrical pattern in a plane perpendicular to a wire carrying current..................................	6
Why hammering a metal rod tends to produce a temporary magnet if the rod points toward the magnetic pole..................................	4
Why magnetized drillings cling to the drill......	4
How drillings accumulate symmetrically around a wire in a plane perpendicular to a wire carrying current..................................	4
24. An electric current may be produced in three ways: by rubbing or friction, chemical action, and the use of a magnetic field.	
Why static electricity is on objects that are rubbed..................................	2
How direct current is produced in cutting of a magnetic field..................................	1
How batteries produce electricity by chemical action..................................	1
25. An electric current will flow in the external circuit when two metals of unlike chemical activity are acted upon by a conducting solution, the more active metal being charged negatively.	
When a battery is used to test radio equipment..................................	1

TABLE II (CONTINUED)

Principle and Applications	Number of Different Industries
26. An electromotive force is induced in a circuit whenever there is a change in the number of the lines of magnetic force passing through the circuit.	
How direct current is generated and maintained to provide current to run direct current machinery..	2
27. A fluid (liquid or gas) has a tendency to move from a region of higher pressure to one of lower pressure; the greater the difference, the faster the movement.	
When glue drops off the brush onto points of wood.	6
When parts of a room are heated by a heater or by machinery..	6
How hot air is pushed up...........................	6
When the grinding machine is turning at a fast rate, a breeze flows from it.................	6
When the swing door is thrown open...............	6
When the lathes are turning, breeze is forthcoming..	6
Why closing the door creates a breeze............	5
Why motors of the grinders tend to be accompanied by small particles of sawdust................	5
Why the winds attempt to blow the sawdust piles away..	5
How a hydraulic shock absorber works............	4
How oil tends to flow out from the machines......	4
How spray is buffeted about in tiny small particles..	3
Why water in motion tends to produce a breeze and a vacuum..	3
Why a surge of heat is felt around the location of heat source................................	3
How water is used to suck air and spray paint away from the painter.........................	3
When the oil in the stove tends to seek its lower level to feed the fire........................	2
How steam is produced for humidifying the room...	2
How small particles of water vapor tend to drift about and humidify the room..................	2
How the fridgidaire coils cool....................	2
Why sawdust billows up from the resaw............	2

TABLE II (CONTINUED)

Principle and Applications	Number of Different Industries
Why compressed water vapor tends to create a breeze....................................	2
Why the boiler room produces a breeze whenever entered.................................	2
How the heat circulates through the tubes in the boiler..................................	2
How in a larger room there tends to be more movement of air currents......................	2
Why air seems to blow up shafts and stairways....	2
How small particles of yarn tend to mingle as a screen of haze in the room.................	1
Why air is used to hold back water in pipes to prevent freezing...........................	1
Why the plant needs an automatic humidity system.	1
How air and heat tend to circulate the correct heat for weaving of yarn....................	1
How heat developed in the vinegar cylinders tends to help heat the room....................	1
How wind is made by pressurized steam being freed.	1
How heating during the cooking process tends to produce convection around the cooking kettle, and canning jars....................................	1
How heat tends to produce convection over warm and finished jars............................	1
Why water carries the sawdust downstream.........	1
How the bleaching mixture is forced into bleaching tanks....................................	1
How water pressure is obtained from a high water tank..	1
How the dyeing vats are supplied with new mixture..	1
How water is forced through a filter for preparation for use in dyeing.......................	1
How the bubblers work for drinking fountains.....	1
How oil is vaporized into boilers................	1
Why fire extinguishers work......................	1
Why vinegar is conducted from the top of raffia filled cylinders to the bottom................	1
Why exterior tanks are situated higher than inside tanks to facilitate filling.............	1
How pressed cider is drained from pressing machines.....................................	1
How pectin and apple juice is taken from the vacuum machine..............................	1
Why jelly is bottled from cooking tanks overhead..	1

TABLE II (CONTINUED)

Principle and Applications	Number of Different Industries
How prune juice is pumped to tanks for bottling..	1
Why bottled sulpher dioxide gas flows into solution from a cylinder..........................	1
How the wind blows the sawdust into water........	1
Why wind is used to carry and deposit sawdust....	1
How sawdust is thrown into a pile by an electric blower....................................	1
How steam causes upheaval in cooking vats........	1
How steam is used to pump solution by exerting pressure on jelly, vinegar and juices.........	1
How a vacuum helps apple juice to boil at a lower temperature...............................	1
How sulphur dioxide escapes to the air from the surface of the uncovered solution.............	1
How water "draws" paint by vacuum "pull" in the paint pit..................................	1
How steam pressure is pumped up to provide an equally hot temperature in other parts of the building..................................	1
How the smell of hot jelly permeates the room very quickly...............................	1
28. Any two bodies attract one another with a force which is directly proportional to the attracting masses and inversely proportional to the square of the distance between their centers of mass.	
When piles of sawdust are leveled by vibration within the room.............................	7
When the sawdust is dropping on the floor........	6
When the tools fall to the floor................	6
How a stream of oil tends to wash drillings along with it..................................	6
Why holes in the floor are filled with waste stock of sawdust............................	6
Why the pitted surfaces of machinery are filled with workings of the material.................	6
How oil is used as a lubricator and is smoothed out on the surface..........................	6
When different types of sawdust tend to pile up in strata..................................	6
Why heaped up materials are shaken down by vibration....................................	5
How glue is applied to flashings on table and then the flashings are fastened together......	5

TABLE II (CONTINUED)

Principle and Applications	Number of Different Industries
Why different types of filings and cuttings tend to pile in layers..................................	5
Why dirt tends to be tracked in and deposited....	5
When the wood is attracted to the saw............	5
When pieces and bundles of wood drop onto the floor..	5
When two pieces of wood are glued................	5
Why machines are clogged with sawdust or dirt....	5
Why tools are all fastened into place solidly....	5
How mortising of wood is accomplished............	5
When the filings tend to stick to the file.......	4
How drying tends to warp boards..................	4
How steam and moisture run down the windows and collect dust..................................	4
How metal pieces are bolted together to provide strength.....................................	4
How the paint congeals on wood and the wood stretches the paint..............................	4
How particles of dust are in the air, and gather on every surface..............................	4
How metal dust and moisture tends to cement each other into small balls........................	4
Why the walls are dusty with white fine sawdust..	3
Why paint sticks to cabinets.....................	3
How varnish and glue tend to wash particles of sawdust away in drippings......................	3
How paint has a tendency to run together at the bottom.......................................	3
Why more power is needed to saw through logs.....	2
Why the nails tend to fall into grooves on the nailing machines..............................	2
Why particles of sawdust tend to remain on the sandpaper....................................	2
How the feet of workers obtain friction even though the floor is slippery..................	2
Why dirt tends to accumulate on the floor........	2
How walking has worn stairways...................	2
How plywood tends to crack open when dried out too much.....................................	2
How waste stock tends to arrange itself when flowing down into piles..........................	2
How balls of sawdust tend to form, and freeze together when sawdust is piled..................	1
How yarn dust tends to unite into balls of dust..	1
How folded twist tends to settle into definite layers under the pressure of packing..........	1
How carbon accumulates in the furnace and tends to become harder as pressure grows on the surface..	1

TABLE II (CONTINUED)

Principle and Applications	Number of Different Industries
Why all the ends of elastic and yarn are separated before weaving to prevent compacting....	1
How soil and sawdust pushed together by ice tends to compact to a more solid form..............	1
How weights tend to unite leatherette to wood as one solid piece............................	1
Why the vibration of apples caused by shovelling or channelling causes a settling of the surface of a pile................................	1
Why sugar tends to settle to bottom when a scoop full is taken from the reservoir.............	1
How pumice cakes are made from pumice dust drying under pressure.........................	1
Why worked prunes deposited in piles tend to solidify into one sticky mass................	1
How water tends to bring sawdust away from the pile..	1
How the streams of water tend to take paint particles to one pool and build them into a mass.	1
How the webbing dries out from the higher surfaces first and continually runs down the more wet surfaces..............................	1
How the moisture from the humidifiers tends to wash dust from the air.......................	1
How the sprinkler accidentally worked in loosening its spray and tearing the dirt and dust from the ceiling and scattering it on the floor..	1
How alcohol is dispersed and washes raffia down in the vinegar cylinders.....................	1
How apples are washed down to the conveyor by water...	1
How water is used to wash equipment of sticky substance by pressure.........................	1
How cider drippings tend to wash sediment with it to be filtered later.........................	1
How water is used to wash vinegar barrels and detach dirt from the sides.....................	1
How jelly and juice wash solid matter along with it, and is composed of those ingredients......	1
How a dip for cut apples settles the small pieces to the bottom and frees the larger pieces for use..	1
How water tends to drip out of pipes and fall to the lowest level...........................	1
How nails arrange themselves when thrown into a hopper.......................................	1

TABLE II (CONTINUED)

Principle and Applications	Number of Different Industries
How varnish is put onto boxes after stain........	1
Why prunes tend to arrange themselves when thrown into a truck from a wheelbarrow...............	1
How glue tends to be rolled more evenly on a flat area than when brushed on.....................	1
How sticky prunes stick to the floor and the floors stick to the cooking kettles and to the prunes....................................	1
How pressure is maintained on a board between rollers for resawing.........................	1
Why leatherette is glued to cabinets.............	1
How paint changes the color of water, and adheres to the plane surfaces in a lump...............	1
How the spools stay on the equipment and machinery.	1
How the end of the yarn falls to the floor when broken.....................................	1
How oil tends to fall to the floor of the furnace when oil is sprayed into the doors............	1
How a fine mist for humidity tends to settle toward the floor................................	1
How the dust from the yarn tends to settle to the lower levels below the machinery..............	1
Why water runs from the soaked yarn back into the vats.......................................	1
How balls and rolls of elastic are placed on the table in piles...............................	1
How the oil drops to the pans and is kept from the floor..................................	1
Why vinegar tends to wet the cylinder around it..	1
How jars of jelly on a conveyor attract one another......................................	1
How the cylinder attracts the mass of prunes thrown into it..............................	1
How the apples tend to fall to the floor.........	1
How the jars are attracted to cardboard boxes....	1
How the barrels of vinegar are attracted to the floor......................................	1
How the caps are attracted to the bottles of juice......................................	1
How the liquids and solids are attracted to the outside of their containers..................	1
How webbing is stretched tightly when it is washed and dried (shrinkage)..................	1
How powdered elastic tends to vibrate powder to a lower surface of the floor...................	1

TABLE II (CONTINUED)

Principle and Applications	Number of Different Industries
How the cartons of yarn and rubber accumulate in storage....................................	1
How water seeps from bleached or dyed yarn or webbing....................................	1
29. Movements of all bodies in the solar system are due to gravitational attraction and inertia.	
30. The pressure in a fluid (liquid or gas) in the open is equal to the weight of the fluid above a unit area including the point at which the pressure is taken; it therefore varies as to the depth and average density of the fluid.	
How machines are gravity oiled..................	5
When molten metals tend to flow to the floor and spread out....................................	3
Why water flows faster under the mill and tends to carry sawdust away.........................	1
Why varnish has to have a special receptical because of its density............................	1
Why cones of yarn are bleached under pressure....	1
How the automatic trap works to fill the bleaching and dyeing vats.........................	1
How pressure regulates the level of vinegar cylinders....................................	1
How pressure produces flow from a higher cylinder to a lower one................................	1
How water is used to wash apples along a pit.....	1
How the bottles are filled to the desirable level by correct arm suction of the cylinder........	1
How tanks are stored outside of the factory, and tends to have vinegar to seek the level of the tanks inside....................................	1
Why webbing is lowered to the base of the tank in dyeing and in bleaching........................	1
How gauges are used to tell the correct height of the vinegar in the cylinder..................	1
Why a full keg of vinegar has to be completely waterproofed to prevent loss of liquid........	1
How water pressure is obtained from a high water tank....................................	1

Principle and Applications	Number of Different Industries
31. Bodies in rotation tend to flyout in a straight line which is tangent to the arc of rotation.	
How sawdust flies from the saw....................	7
Why the hammer head tends to work off its handles.	7
How pieces of wood are thrown into piles.........	6
How filings on the band saw tend to fly out in a straight line when the blade curves...........	6
How drillings turn out perpendicular to the drill on the block.................................	5
How sparks fly off the grinding wheel............	5
How the force of being thrown off of the rollers helps to tighten belts around the drive wheels.	5
How sawdust collects in piles near the saw.......	5
Why drive belts which become loosened tend to fly from drive wheels..............................	4
How the wrench tends to fly off the nut when the wrench is turned at a rapid rate..............	4
How a central well in a machine tends to oil the bearings...................................	3
How a chisel is applied perpendicularly to stock turning in a lathe...........................	3
How sawdust and chips are thrown away from the work while the plane is working..............	3
Why saw blades tend to work off rollers in motion.	3
How a horizontal portable grinder planes surfaces....................................	2
How cuttings come off of a die..................	2
How centrifugal force of the wheel tends to unite particles of sawdust on the inside of the outer rim of the wheel when it is in motion...	2
How the roller is used to glue the leatherette for protecting the wood......................	1
How the broken yarn swings out from a revolving cone or spool.............................	1
How yarn dust is thrown off of spools in motion..	1
How water is squeezed out of dyed webbing........	1
How cones of yarn are bleached under pressure from solution in the center of the cones......	1
How a covering of yarn is put onto elastic.......	1
How water is distributed from a rotating fire sprinkler................................	1
How alcohol is indispersed lightly over raffia in the vinegar cylinder......................	1
How the top sediment of jelly clings to the side of the kettle.............................	1

TABLE II (CONTINUED)

Principle and Applications	Number of Different Industries
How a barrel is rotated to wash the sides within......................................	1
How outside cogs on horizontal wheels distribute jars equally into bottling and labelling machines....................................	1
How apples, jars, and juices are thrown away from conveyors at the end of each conveyor line....	1
How pumice is dried by steam in a revolving cylinder....................................	1
32. A body immersed or floating in a fluid is buoyed up by a force equal to the weight of the fluid displaced.	
How sawdust stays floating in water..............	1
Why sawdust in oil tends to float even higher on the surface of the oil than in water..........	1
Why paint tends to settle in water...............	1
Why chips and sawdust tend to stay on top of glue in the glue pot.........................	1
Why chips seem to float in varnish, to a greater extent than in water..........................	1
How cones of bleached material are placed into solution and displaced liquid helps to cover them.....................................	1
How webbing being dyed or bleached tends to raise the level of the tank........................	1
How the tank maintains the level of bleach automatically by the correct displacement measured by a rod in the solution......................	1
How raw sections of apple are supported in cider.	1
How solid matter in jelly lifts the surface of the liquid almost sixty-five per cent.........	1
How prunes in tanks displace water to make prune juice mixture...............................	1
How a paddle used to stir jelly displaces some jelly.....................................	1
How raffia and worms causes a displacement in the vinegar vats..............................	1
How cut apple tends to displace sulphur dioxide solution and be coated at the same time by it.	1

TABLE II (CONTINUED)

Principle and Applications	Number of Different Industries
33. The pressure at a point in any fluid (liquid or gas) is the same in all directions.	
How the hydraulic arm works in allowing the saw blade to descend more slowly..................	2
Why the brush when put into paint or glue tends to push the liquid up.........................	2
Why water has as much actual pressure as the container in which it is placed...............	2
Why equal pressure is provided in bleaching yarn to maintain an even white color...............	1
Why webbing is lowered to the base of the tanks in dyeing and in bleaching....................	1
Why water in the boiler is kept at a certain level to provide more steam.....................	1
How gauges are used to tell the correct height of the vinegar in the cylinder..................	1
Why a full keg of vinegar has to be completely waterproofed to prevent loss of liquid........	1
How the hydraulic press works to force weight onto the mash frames for cider................	1
Why the liquid impregnates the paddle used to stir it...................................	1
34. Heat is conducted by the transfer of kinetic energy from molecule to molecule.*	
35. When two bodies of different temperature are in contact, there is a continuous transference of heat energy from the body of higher temperature to the one of lower temperature, the rate of which is directly proportional to the difference of temperature.*	
Why all parts of the motor are warm..............	7
Why both the nail and the hammer head feels warmer after driving a nail..................	7
Why all the uninsulated parts of the stove are hot..	6
Why the wood feels warm a few inches from the freshly sawed cut............................	6

*All applications assigned to principle number 35 are also considered to be assigned to principle number 34.

TABLE II (CONTINUED)

Principle and Applications	Number of Different Industries
Why wood tends to dry out........................	6
Why all the sawed stock feels warmer.............	6
Why the sun tends to heat up around the stock where it strikes............................	6
Why drilled stock tends to be warmer after drilling..	6
When the hammer is held in the hand..............	6
How a heater heats the air in the room...........	6
How the heater dries out boards..................	6
How the saw is heated up and loses its temper....	5
When the milling machines and lathes are working there is a transfer of heat from the cutting tool to the stock..........................	5
When friction of drilling heats the stock and the drill equally..........................	4
Why oil is used on drilling surfaces.............	4
How a motor burns out............................	3
How paint is dried gradually and more thoroughly.	3
When metal is chiselled, friction heats both objects.......................................	3
When stock is cut by burning, the objects are heated as hot as the arc to make it easier to cut through..................................	3
When the wood is loaded onto a cold truck from a warm room..................................	3
How the friction of a rotary grinder on wood warms up the wood and air around it...........	3
How heat is conducted in the room................	2
How glue is dried completely.....................	2
How the warm solution heats the containers it is in..	2
How the heat is transferred from the room to colder material..............................	2
How steam tanks heat the room, and transfer heat energy to the air............................	2
How the hot boiler heats the air about the small room to an eighty-five degree heat............	2
Why glue dries around a warm radiator a great deal faster...................................	2
Why the worker's feet are always cold in winter..	2
How the radiators and steam tend to help dry out the room....................................	2
How cold air comes in and cools the room off.....	2
Why heat has to be completely and continually furnished the room to maintain an even temperature....................................	2

TABLE II (CONTINUED)

Principle and Applications	Number of Different Industries
How a soldering iron works......................	2
How the forge is used to heat metals............	1
How the sander belt tends to heat wood, and wear it away..	1
How the soldering iron is used to supply heat for melting solder.................................	1
How bleached yarn is dried......................	1
How dyed elastic and yarn is dried..............	1
How yarn with friction on machinery tends to warm the machine and dry out the yarn.............	1
How cold yarn tends to cool the room............	1
How heat below a floor tends to warm the floor...	1
How the yarn woven around elastic tends to be the same temperature in the finished webbing......	1
How the apple juice is boiled in a partial vacuum to obtain extract............................	1
How apple juice is pasteurized two times.........	1
How steam cooks the jelly mixture................	1
How the hot jelly mixture warms everything it comes into contact with.........................	1
How refrigeration takes the heat out of apples to prevent decay................................	1
How steam is used to cook prune juice, clean barrels, and other receptacles................	1
How heat is absorbed by the hard cider which tends to be turned into vinegar within the cylinders.	1
How the warm prunes heat the wheelbarrow, floor and truck when the hot prune vat is cleaned..	1
How the heat of the working vinegar helps to heat the vinegar plant...........................	1
How the storing of steam tends to help the receptacle to become extremely hot.................	1
How the forge and heated stock are known to heat up in the hands............................	1
Why a holder has to be used to handle a stove lid handle..	1
How heated kettles of boiling jelly tend to conduct heat to the stirring paddle..............	1
How the elastic on steamed rollers tends to have the liquid settle next to the roller, and dry out...	1
Why the hot steam reaches all areas and is used to sterilize receptacles......................	1
Why the dried webbing feels warm to the touch....	1
How the looms are warmed up from friction of its moving parts................................	1

TABLE II (CONTINUED)

Principle and Applications	Number of Different Industries
How glowing bulbs help to heat telegraph recording tape and sets	1
How alcohol is warmed and oxidized	1
How pectin extract is made under partial vacuum	1
How all cooking from one source tends to heat and cook all of the solution	1
How warmer jars tend to heat the conveyor	1
How hot jelly jars warm cool water sprayed on them	1
How apples lose their heat after being put into deep freeze	1
How hot jelly and juice tend to warm the box in which they are placed	1
36. The lower the temperature of a body, the less the amount ofenergy it radiates; the higher the temperature, the greater is the amount of energy radiated.	
How the stove works	7
When the saw radiates heat	7
When the machines are heated up	7
How worked starch disposed of its heat	6
How the building is warmed by the sunlight	6
How electrical circuits become warm and heat the surrounding wood area	5
How the building and floors become cold on a cold day	4
How the body becomes cold when the floor takes heat away	4
How radiators tend to dry materials painted more quickly	4
How warm chips and sawdust tend to dry out by their own heat	3
How the lathe machine and area about it is heated.	2
How the boiler room seems to radiate heat faster and to a greater extent	2
How the machine cools down when it is turned off.	2
How tempering takes place	1
How warm jars tend to radiate heat to the machinery	1
How in pasteurization heat is radiated to all the ingredients in the jar, and to the machinery as well	1
How steam is used to heat metal drives and the heat radiated dries the webbing	1

TABLE II (CONTINUED)

Principle and Applications	Number of Different Industries
How heat is radiated through the cylinder in the vinegar room..................................	1
37. Heat is transferred by convection in currents of gases or liquids the rate of transfer decreasing with an increase in the viscosity of the circulating fluid.	
How the heat of sawing is transferred to all parts of the room................................	6
How the room is heated by a central stove........	6
Why heat is convected from the grinding wheel....	6
How hot air is pushed up..........................	6
Why the floor seems to be so cold and yet the rest of the room seems normally warm..........	5
How the heat of drilling is lowered with proper lubrication....................................	4
Why heat is convected by fans to speed up heating.	4
Why glue dries faster if a warm air current is convected around the glued surface............	3
Why painted cabinets are placed nearer to windows for better drying with the convection of air..	3
Why the boiler room is heated to such a warm temperature..................................	2
Why elevator shafts and stairways are blocked off to keep the heat in the room.................	2
How the steam storage tank tends to keep the machine maintenance room warm..................	2
Why water under the factory seems to cool the entire factory.............................	1
How the humidity of the room is maintained.......	1
When the direct current generator works, the warmth of the motor is noted in being conducted about the rooms.........................	1
How the steam is conducted off the dryers when webbing is being dried.........................	1
How the room is kept warm by the help of the overhead drives..............................	1
How steam is convected to all parts of an enclosure for sterilizing bottles, barrels and other receptacles............................	1
How sulphur dioxide gas is convected about the area where it is used in solution around a hot area of the industry..........................	1

TABLE II (CONTINUED)

Principle and Applications	Number of Different Industries
How frost is kept to a minimum in a deep freeze by convection of air..........................	1
How the hot juices in vats are moved in convection currents due to the heat given off by cooking...	1
How air and heat tend to circulate the correct heat for weaving of yarn.........................	1
How heat during the cooking process tends to produce convection around the cooking kettle and canning jars.................................	1
How heat tends to produce convection over warm and finished jars..............................	1
When the drying room has direct ventilation......	1
How condensation takes place around the entrance to deep freeze................................	1
38. Every pure liquid has its own specific boiling and freezing point.	
While oil is used as a lubricator on fast moving machinery.....................................	6
How glue is worked..............................	4
How kerosene is vaporized for burning............	3
Why steel is watched so that the melting point is not reached in tempering........................	3
Why oil congeals when it becomes cold............	2
Why glue and paint harden at a room temperature..	2
Why water is used to make steam for drying purposes, dyeing and heating........................	2
Why water carrying sawdust is frozen in cold weather, and the sawdust accumulates............	1
Why stain works into wood better when the stain is warm.......................................	1
How cider and vinegar, apple juice, prune juice has to be guarded against freezing............	1
39. The higher the pitch of a note, the more rapid the vibrations of the producing body and *vice versa*.	
When the saw runs through different types of stock	6
How the machines hum at different pitches.........	6
Why faster hammering may produce a higher sound...	6
Why the grinder revolves faster with a higher sound..	6

TABLE II (CONTINUED)

Principle and Applications	Number of Different Industries
When the hammer strikes a nail or board..........	5
When the saw meets resistance the sound changes in pitch....................................	5
When lathes vibrate at different pressures of cutting and emit different sounds................	4
How the plane sounds when different thickness of wood are planed............................	4
When stock is pushed against the saw or drill with more force..............................	4
How the mortising (tonguing) machine increases in pitch when different knots are cut............	2
When the sander is meeting with heavier force, the pitch becomes lower......................	1
Why when parts of the winding machine is used, a separate distinct noise is produced...........	1
Why the sound of pressurized oil has a pitch when thrown out via a nozzle......................	1
Why overhead drive tends to produce more noise...	1
Why the vibration of jars together seems to increase the pitch............................	1
How each strand of yarn makes a sound if stretched when the machinery is in action around it..	1
40. Musical tones are produced when a vibrating body sends out regular vibrations to the ear while only noises are produced when the vibrating body sends out irregular vibrations to the ear.	
Why all the vibrations in the shop produce noise instead of musical tones......................	7
Why the mingling of noise causes a din that one cannot hear above............................	5
When all the pitches are combined in running a textile industry, the noise produced means many irregular vibrations received by air..........	1
Why jars clanking together often produce a musical tone....................................	1
How each strand of yarn makes a sound if stretched when the machinery is in action around it..	1
How each part of a loom in action tends to have a regular vibration, but together they make noise because of a difference in pitch.............	1

TABLE II (CONTINUED)

Principle and Applications	Number of Different Industries
41. Energy is often transmitted in the form of waves.	
When alternating current is used in running machinery	7
Why sound is heard when a noise is made	7
Why flourescent lighting is seen moving the hand to get the stroboscopic effect	6
Why vibration is felt through the floor when machinery is running	6
Why the sound reechoes through the building when something is dropped	6
Why the saw produces a different hum depending upon resistance	5
Why anything in motion tends to make noise	5
Why the windows rattle while machinery is in motion	4
Why machinery tends to produce a wavering miscibility in liquids	3
Why the vibration of a building produces waves in varnish pool	1
Why leatherette tends to vibrate while hanging loosely in the air	1
How direct current produces a pulsating wave different than the wave for alternating current	1
How the stretched yarn tends to vibrate according to the motion of machinery	1
Why the elastic is stretched and caused to vibrate when woven into webbing	1
How the elastic is held taught and vibrates according to the sound of machinery when being covered	1
42. When waves strike an object, they may either be absorbed, transmitted, or reflected.	
When the sound waves bounce off the walls as the materials are sawed	7
How hammer sounds resound from walls and surfaces of the room	6
How light comes through the windows and falls on light or dark surfaces	6
When light from incandescent bulbs reflect from the motor surfaces	6
When light from the windows hits old stock, and is absorbed	6

TABLE II (CONTINUED)

Principle and Applications	Number of Different Industries
When hammering reverberates from other walls when machinery or hammers are pounding............	6
When sound is muffled by wood work so it cannot be heard outside the factory.................	6
Why dust in the air tends to make the place dark.	6
Why a sawdust pile is easily seen...............	4
When light hits newly polished, or cut stock, it is reflected..............................	3
How the hammering machines reverberate as a din within the building, and through the stock itself...	3
Why a different whine is noted at different distances from the machines in the shops.........	3
Why the light unpainted cabinets tend to reflect more light.................................	2
How all the machines running at once produce a great deal of noise.........................	2
How certain integral parts of machinery vibrate more than other parts.......................	2
Why the floor vibrates under machinery..........	2
Why windows rattle when a machine is in motion...	2
Why steam tends to make the room darker.........	2
Why pools of varnish tend to vibrate in small ripples......................................	1
Why separate pieces of equipment have grooves to prevent shuttles from vibrating from the machinery......................................	1
Why strands of yarn vibrate in the room when being fed into the machine...................	1
Why different departments are segmented from one another......................................	1
Why heavy machinery and spools if dropped make parts of the floor vibrate to the breaking point...	1
How the hammering on an empty barrel is reflected, absorbed and transmitted to the air inside the barrel.............................	1
How dripping juices, water, vinegar tend to make a series of waves on the receiving fluid......	1
How the reflections of light from jars and caps and copper kettles seem to lighten the room...	1
When light strikes the jelly in jars, only certain color, or colors, are transmitted........	1
How the jars of jelly, juice, and vinegar appear to be one color due to straight lines passing through materials..........................	1

TABLE II (CONTINUED)

Principle and Applications	Number of Different Industries
How heavy rolls of twist are conducted from the floor by block and pulley..........................	1
43. When light rays are absorbed, some of the light energy is transformed into heat energy.	
Why the sunlight tends to help warm the room to help in drying....................................	7
Why an incandescent bulb near a piece of metal makes the metal warmer..........................	5
How a flourescent light helps to produce heat in and about the reflector........................	5
How some of the light rays passing into a solution tend to help warm the solution...........	2
How the light rays from fire in a stove pass through mica doors and can be "felt" outside..	2
How in outside vinegar storage the tanks are heated by sunlight to facilitate the working of cider..	1
How an apple spoils when it drops onto the floor and light energy turns into heat energy to speed its decay.................................	1
Why light energy tends to heat worms enough to kill them in making vinegar.....................	1
44. The darker the color of a surface, the better it absorbs light.	
When the area of working is dark.................	7
Why the dark machinery absorbs a great deal of light..	6
Why it takes extra illumination to light up settings..	6
Why new cuttings reflect more light.............	6
Why dark surfaces seem warmer when sunlight shines on them......................................	6
Why the building is painted white to absorb less light..	6
How the darker drawings can be seen better on white paper.....................................	6
How lighter surfaces seem to show more dirt......	6
Why certain surfaces are apinted darker to shield the worker from reflections and glare.........	6
Why bark is still on the log.....................	5
Why dark clothes are worn to hide the dirt.......	5

TABLE II (CONTINUED)

Principle and Applications	Number of Different Industries
Why dark surfaces are placed where dirt would show	4
How rusted stock seems to make the room darker	4
Why dark opaque glass is used to prevent light from hurting the eyes	3
Why ice tends to reflect more light than the same amount of water	1
Why the white yarn is used in machines to enable more reflection and better visibility	1
Why surfaces are dyed to a color as a final step and each color is combined to the nearest shade	1
Why white webbing is covered to prevent its getting dirty and absorbing a greater amount of light	1
Why skylights are provided to maintain as much light as possible when around the dark machinery	1
Why more light is present when particles of the white yarn cover the floor and cover the darker surfaces	1
Why the tanks for storage of vinegar are dark to absorb light and heat for curing vinegar properly	1
How vinegar, jelly andjuice tend to absorb light, and transmit only the color they contain	1
How glass jars transmit nearly all light because they contain little color	1
How dark worked apples absorb light and produce heat on their surfaces	1
How the large vats absorb light and tend to darken the room	1
Why it is easier to follow the course of white rather than darker yarn through machinery because it reflects more light	1
Why light is absorbed when hitting piles of apple corings and peelings	1
45. The intensity of illumination decreases as the square of the distance from a point source.	
When a light meter is used to determine the lighting conditions necessary for workmen on a machine	7
Why a more intense light is needed to brighten up machinery settings, and other working areas	6

TABLE II (CONTINUED)

Principle and Applications	Number of Different Industries
Why special illumination has to be furnished to read machinery settings........................	6
Why individual lights, often movable, are used when machinery is being operated or repaired..	5
Why long flourescent lights are used to maintain an even minimum amount of light...............	5
Why increased window space provides a greater amount of light in the daytime................	3
Why a great deal of wall space is made use of to provide more windows.........................	2
Why the interior of the vinegar works is so dark because of the distance from the light source caused by the large vinegar cylinders.........	1
46. Radiant energy travels in waves along straight lines, its intensity at any distance from a point source is inversely proportional to the square of the distance from the source.	
When the room is illuminated by incandescent lamps..	7
When sunlight enters the room through a window...	7
How the stove works.............................	7
When the saw radiates heat.......................	7
Why heated metals radiate more heat and transfer heat to other pieces of metal.................	6
How the floor is heated around a warm machine....	6
How worked stock disposed of its heat............	6
How the building is warmed by the sunlight.......	6
How a heated wire warms woodwork by radiation....	5
How electrical circuits become warm and heats the surrounding area.............................	5
How warm machinery tends to dispose its heat.....	4
How the building and floors become cold on a cold day..	4
How the body becomes cold when the floor takes heat away......................................	4
How radiators tend to dry materials painted more quickly....................................	4
How soldering and welding are accomplished.......	3
How wood stock lying on a machine becomes warm...	3
Why gloves are used on hands in arc welding to prevent burning.............................	3
How warm chips and sawdust tend to dry out by their own heat................................	3

TABLE II (CONTINUED)

Principle and Applications	Number of Different Industries
Why sunlight streams in practically a straight line in a dusty room	2
How the room becomes thoroughly heated and objects become warm within the room	2
Why the radiation in an industry tends to be noticed in a small area due to its machinery	2
How the machine cools down when it is turned off	2
How hot jars and bottles in contact with the conveyor help to heat the conveyor	1
How the heat is radiated through the cylinder in the vinegar room	1
How heated bleach baths have a hot area over them	1
How steam is used to heat metal drives and the heat radiated dries the webbing	1
47. When light rays pass obliquely from a rare to a more dense medium, they are bent or refracted toward the normal and when they pass obliquely from a dense to a rarer medium, they are bent away from the normal.	
How the sun strikes, and comes through the window	7
How the flourescent light goes out through the window	6
How light rays are bent upon entering the bleaching solution	1
How light rays seem to bend about the mica windows when light comes from the fire	1
How light rays pass through amber jelly	1
How light rays pass through vinegar or apple juice in bottles, and are bent upon their exit	1
How light rays are bent when they pass through gauges and apparatus for testing different solutions	1
How light rays are bent when they pass through a constantly falling solution	1
48. An image appears to be as far back of a plane mirror as the object is in front of the mirror and is reversed.	
49. Parallel light rays may be converged or focused by convex lenses or concave mirrors; diverged by concave lenses or convex mirrors.	
Why a reflector helps to give more light for working on machinery	6

TABLE II (CONTINUED)

Principle and Applications	Number of Different Industries
Why convex shafts seem to throw light in a wider direction..	6
How bent stock converges or diverges light.......	5
Why flourescent shields are made to converge light on a floor area...........................	4
Why a wide band saw focuses points of light from its bent surfaces.............................	4
Why bent parts of cabinets seem to fill less space, and look better.........................	2
How contact points that are rounded produce diffused rays of light............................	2
How bent surfaces of machinery diverge or converge light rays................................	2
How light is reflected from a worn floor surface.	2
How parts of the loom tend to converge or diverge light rays by employing bent surfaces.........	1
How rounded spools tend to diverge light rays....	1
How rounded dryers of stainless metal tend to diverge light rays................................	1
How elastic webbing tends to converge light rays when the surface is concave.....................	1
How small spools of rayon tend to appear brighter to the eyes because the sheen of the material diverges more light............................	1
How filled bottles tend to have the ability to reflect by diverging or converging the rays of light from curved parts of the bottle.........	1
How the silver surface of a partial vacuum machine tends to diverge or converge light rays.	1
50. Protons and neutrons only are found in the nucleus of an atom.	
51. In an uncharged body there are as many protons as electrons and the charges neutralize each other while a deficiency of electrons produces a plus charge on a body and an excess of electrons produces a negative charge.	
Why the motors are grounded to take away charge..	7

TABLE II (CONTINUED)

Principle and Applications	Number of Different Industries
Why all wood products seem to be non-conductors..	4
Why the rubbing of iron produces static electricity................................	3
Why overhead drives and friction of yarn on surfaces produces static electricity dangerously.	2
52. An electrical charge in motion produces a magnetic field about the conductor, its direction being tangential to any circle drawn about the conductor in a plane perpendicular to it.	
How a motor employs the use of electromagnets....	7
How coils on transformers help step voltage up or down....................................	6
Why filings tend to fall in a symmetrical pattern in a plane perpendicular to a wire carrying current.................................	6
53. All materials offer some resistance to the flow of electric current, and that part of the electrical energy used in overcoming this resistance is transformed into heat energy.	
Why the heat energy is derived when a motor runs.	7
Why an incandescent bulb lights up and becomes hot....................................	7
Why too many machines running on the same circuit overheats the lead in wires..................	6
Why the transformer is needed..................	6
How the arc works to burn through metals.........	3
Why copper is found to be used as a chief conductor of electricity.........................	2
How tubes are lighted up in a radio set..........	1
How resistors are used in coding sets............	1
Why a broken end of yarn drops a bar that gives resistance and opens a circuit................	1
54. The resistance of a metallic conductor depends on the kind of material from which the conductor is made, varies directly with the length, inversely with the cross sectional area, and increases as the temperature increases.	
Why certain size wire connects certain machinery.	7

TABLE II (CONTINUED)

Principle and Applications	Number of Different Industries
Why different caliber of wire is used when voltage is increased...........................	6
Why machinery farther away from source maintains less power............................	6
Why each loom has a single individual drive for more efficiency and less resistance.......	1
55. The electrical current flowing in a conductor is directly proportional to the potential difference and inversely proportional to the resistance.	
Why motors are connected on parallel rather than series circuits..........................	5
Why there is a dimming of lights when a machine is turned on..................................	5
Why voltage is stepped up for individual machines with individual drives.........................	5
Why special equipment has to be tested for 220 volt fifty cycle output for foreign countries.	1
Why transformers are used to increase potential difference....................................	1
Why a rheostat is used in series with a motor which operates direct current machinery.......	1
56. Electrical power is directly proportional to the product of the potential difference and the current.	
How a machine acquires power to run..............	7
Why the potential difference is increased to run more machines..................................	6
Why each major machine has to have a separate switch...	6
Why the lighting is separated from machinery currents...	5
Why voltage is stepped up for individual machines with individual drives.........................	5
Why an electric line has a transformer to permit more machinery in operation at once...........	5
Why many machines use a different voltage and current to do work............................	4
How voltage is stepped up to provide more electrical power to run the arc welder........	2

TALBE II (CONTINUED)

Principle and Applications	Number of Different Industries
Why each motor on a machine has the wattage stamped on it for its best use................	2
How a rheostat is used to speed up direct current machinery..................................	1
Why individual voltage and current or resistance squared multiplied together determines the amount of power needed to run equipment.......	1
57. When a current-carrying wire is placed in a magnetic field there is a force acting on the wire tending to push it at right angles to the direction of the lines of force between the magnetic poles, providing the wire is not parallel to the field.	
How a motor operates on alternating current......	7
How a motor operates on direct current...........	2
58. The atoms of all radioactive elements are constantly disintegrating by giving off various rays (alpha, beta, and gamma) and forming helium and other elements.	
59. The energy which a body possesses on account of its position or form is called potential energy and is measured by the work that was done in order to bring it into the specified condition.	
When the boards are thrown from the truck in unloading..................................	6
When the boards are picked up for first sawing...	6
Why the boards are kept on the same level when they are worked on in the proceeding processes.	6
When lumber is stacked...........................	6
Why bundles are stacked and not moved............	6
Why saw-horses and machines are set at the same height so easy transfer of metals can be made.	6
How cut stock falls to the floor when sawed through..	6
When wood rests on a platform....................	6
How drills are supported by springs and hydraulics to require less muscular energy for drilling...	4
Why hydraulics are used to support the weighted saw from descending too heavily...............	3

TABLE II (CONTINUED)

Principle and Applications	Number of Different Industries
Why the pully and chain is used to lift and store stock..	3
Why the saw is placed so as to drop down to cut lumber stock..................................	3
Why water is pumped to a higher surface to permit a longer fall and more vacuum..................	3
Why cabinets are conveyed to higher portions of the factory for better loading onto platforms.	2
Why a log on a truck is easy to push into a lower place but difficult to lift....................	1
Why sawdust drops through the floor with other waste products to be discarded................	1
Why exceptionally heavy spools and cartons are handled nearest the machinery when brought into the industry..............................	1
How spools spin and produce a fuzz that falls and accumulates on the floor.......................	1
Why the looms are placed at the normal height that a man can best work.......................	1
Why the heavier rolls of yarn and elastic are placed higher on the machine to release their ends more easily..............................	1
Why webbing, yarn and elastic are lowered into vats..	1
How the cider is gathered by the fall through the floor holes into tanks........................	1
How the apples are places in bins and drop to the handling stages.............................	1
How the cider mash is dropped onto the press frames..	1
Why the vinegar barrels are higher than the processing cylinders.............................	1
When the pump is used to get alcohol from base of vinegar cylinder to the top of the cylinder for oxidation..................................	1
Why the cooking vats for jelly are placed above on a second floor to be more easily emptied into jars..	1
How the filters of apple juice have a different potential to provide the trapping of sediment for a drop in the liquid through a filter.....	1
How apple waste is shovelled and deposited in piles..	1

TABLE II (CONTINUED)

Principle and Applications	Number of Different Industries
60. When the resultant of all the forces acting on a body is zero the body will stay at rest if at rest, or it will keep in uniform motion in a straight line if it is in motion.	
Why drilling on a movable block tends to push the block in another direction........................	5
How wood vibrates off a machine in motion........	3
How the resaw works................................	1
How the yarn is distributed evenly in rolling....	1
How the webbing is rolled evenly for delivery....	1
How webbing is woven, yet has to be closed together separately because of two or more actions in weaving..............................	1
How the conveyor deposits bottles, waste apple, apples in a heap some distance from the end of the conveyor belt.............................	1
How prunes are thrown into a truck from a moving wheelbarrow.................................	1
61. When one body exerts a force on a second body, the second body exerts an equal and opposite force on the first.	
When an object is picked up......................	7
When the doors are opened........................	7
How wood is cut..................................	6
When the platforms are moved in sawing, or transporting..	6
Why bearings are hardened to take care of smaller wear..	6
When the wood rests on a platform................	6
When boards are slid over one another............	5
When the glue is brushed onto wood...............	5
How a regular circular saw is pushed against the wood and the wood tends to resist it..........	5
How the drilling takes place on the object and more pressure is needed to start the drill....	5
Why machines wear away materials rapidly and evenly...	5
Why a punched hole is the start of drilling......	5
Why hammering tends to heat up both hammer and bolt...	4
How a planer pushes against wood and the wood against the plane.............................	4
How the drills bore into the material............	4

TABLE II (CONTINUED)

Principle and Applications	Number of Different Industries
How force is applied to push surface into a different shape	4
Why a log exerts pressure on the saw and the saw on the log in order to cut through it	2
How wood is forced against the re-saw and the re-saw cuts through the wood	2
How glue press holds against the press as much pressure as the press holds against the wood	2
How all the equipment on floors in the industry are held in place	2
How bundles of yarn stay firmly on the floor and the floor holds the bundles up	1
How the machines hold spools, cones, and elastic as elastic spools and cones exert their combined weight on the machine	1
How rolls of elastic pushed into cartons (packed) exert pressure on the packing carton	1
How the press exerts pressure on the flats of cider apples and the flats exert pressure against the press	1
62. When pressure is applied to any area of a fluid (liquid or gas) in a closed container, it is transmitted in exactly the same intensity to every area of the container in contact with the fluid.	
How the hydraulic saw works in providing equal pressure for sawing	3
How the drill is lowered to take its position for drilling	2
How glue is begun to be mixed	2
How steam pressure is maintained for heating an entire building	2
How the hydraulic arm works in allowing the saw blade to descend more slowly	2
How steam pressure is maintained to dry bleached and dyed webbing	1
How bleach is used to dye cones of yarn without unrolling the yarn	1
How the humidifying system works to provide an equal amount of moisture to the air under pressure	1
Why pressure of air in pipes is used to hold water back to prevent freezing of pipes in the sprinkler system	1
How the press is lowered by hydraulics onto the cider frames	1

TABLE II (CONTINUED)

Principle and Applications	Number of Different Industries
Why the water in the boiler is kept at a certain level to provide more steam....................	1
63. The average speed of molecules increases with the temperature and pressure; conversely, the temperature and pressure increase as the average speed of molecules increases and decrease as the average speed of molecules decreases.	
When boards are drying in the sun................	4
How the wood heats up and contracts when it begins to burn................................	4
How the glue is dried in the warm room...........	3
Why steel becomes harder when cooled quickly at a hot temperature...............................	3
Why burning of metal provides a loss of material.	3
Why oxygen unites with iron when it is hot.......	3
How paint dries..................................	3
How steam is used to provide a hotter steadier heat for drying...............................	2
How hot bleach solution is pressurized to provide better and more complete bleaching.......	1
How steam is used for humidifying to help particles to scatter more quickly................	1
How hot dye solutions tend to dye a stronger color more completely..........................	1
How the oil is pressurized to give molecules and air opportunity to burn faster and hotter.....	1
Why heat is furnished to dry webbing out more quickly..	1
Why humidity helps to keep the yarn at its best condition for weaving, the molecular construction of the yarn being known.................	1
How the movement of molecules is slower when the pressure is lessened..........................	1
How cooking increases molecular action in liquids and allows vaporization and solidification to take place.....................................	1
How alcohol is oxidized faster when heat is present..	1
Why pressurized steam is used to sterilize faster and more thoroughly...........................	1
Why sulphur dioxide escapes to the air from an uncovered solution.............................	1

TABLE II (CONTINUED)

Principle and Applications	Number of Different Industries
64. Condensation will occur when a vapor is at its saturation point if centers of condensation are available and if heat is withdrawn.	
How the equipment seems to rust faster in a colder room, providing the temperature is lowered..	5
Why stock seemed damp when brought in out of the cold..	4
Why the steam room is kept warm and quite well ventilated to prevent condensation.................	2
Why water in the building tends to produce excessive condensation if heated and cooled rapidly.	1
Why condensation takes place in the paint pit around small particles of paint thus taking paint from the air..............................	1
Why the temperature has to be regulated as well as the humidity in keeping the yarn tough for weaving..	1
Why moisture condenses on cold pipes and drops onto floor of room...............................	1
Why moisture is absorbed by flowing convection currents of air and kept from condensing in deep freeze..................................	1
Why condensation produces wetness on cold machinery and pipes...............................	1
65. A change in state of a substance from gas to liquid, liquid to solid, or *vice versa*, or from solid to gas or *vice versa*, is usually accompanied by a change in volume.	
When the wood dries out...........................	5
Why oil is used up and heat is produced..........	5
Why stain and varnish congeal when drying........	4
Why water vapor tends to spread out over a greater volume than actual water..............	4
How oil particles tend to fill the entire furnace heating area................................	1
How jelly shrinks in volume when it has jellied..	1
Why boiling gaseous quantities are boiled off in great amounts but little of the actual solid has disappeared................................	1
Why vinegar seems to produce acetic acid fumes with little loss to the quantity of vinegar...	1
Why parafin, cake form, produces more liquid parafin by volume.............................	1

TABLE II (CONTINUED)

Principle and Applications	Number of Different Industries
Why it takes the weight of more ingredients to make juice, jelly, or vinegar than what is actually completed in solid form of the product....................................	1
66. The presence of a non-volatile substance will cause the resulting solution to boil at a higher temperature and to freeze at a lower temperature than pure water.	
Why it takes a great deal of heat to boil glue...	5
Why paint congeals more at lower temperatures but does not freeze................................	4
Why it takes a great deal of heat to melt metals.	3
Why the base bleach and dye has to be mixed and kept at a higher temperature sometimes greater than that of boiling water....................	1
Why the dye is kept at a very hot temperature and mixed at that of boiling water...............	1
Why the boiling solution boils only slightly and builds the temperature up when heated by steam.	1
How apples are kept below thirty-two degrees F. without freezing them.........................	1
Why jellies obtained a higher temperature than boiling water...............................	1
67. The volume of an ideal gas varies inversely with the pressure upon it, providing the temperature remains constant.	
How a spray gun is used to spray paint...........	3
How the yarn bleaching bath is regulated.........	1
How steam is kept under pressure for drying and heating......................................	1
How a partial vacuum helps to lower the temperature and pressure and allows gas to pass off at a lower temperature..........................	1
How the sulphur dioxide gas is bottled to prevent escape in heavy metal cylinders, and when used expands into the volume regulated by room temperature.................................	1

TABLE II (CONTINUED)

Principle and Applications	Number of Different Industries
68. Whenever an opaque object intercepts radiant energy travelling in a particular direction, a shadow is cast behind the object.	
When the light comes through the windows, shadows are made by all solid objects..................	6
Why inside illumination is needed................	6
Why buildings have windows to let light into the rooms..	6
Why machinery in front of a window tends to limit light coming in that window..................	5
Why walls keep out a great deal of light.........	4
Why artificial illumination is needed............	3
Why small particles of sawdust tend to darken the interior of the building......................	3
Why with an intense arc shadows are produced by machinery in the room........................	3
Why a black glass is worn in a head shield to prevent blinding by the arc..................	3
How carpet partitions tend to keep out the light as well as the cold..........................	1
Why a load of logs shade the interior of the saw-mill and make the need for artificial illumination greater................................	1
Why the complex machinery of weaving takes up so much room and so much light...................	1
Why the material of rubber and all other products produce shadows............................	1
Why the full color of dyed elastic is combined and inspected under bright light..............	1
Why the factory is built and planned in such a way to receive more light from a larger wall area and window area.........................	1
How free steam absorbs light coming into the room and tends to accentuate the shadows...........	1
How the stored boxes of jelly, juice, sugar and apples, and vinegar tend to produce shadows and cast the interior in darkness.............	1
69. The dispersion of white light into a spectrum by a prism is caused by unequal refraction of the different wave lengths of light.	
Why the light when coming through the windows is projected onto the floor with colors of the rainbow......................................	7

TABLE II (CONTINUED)

Principle and Applications	Number of Different Industries
How empty bottles cast light into colors when light is passed through them..................	1
How the test for solid crystals is found in checking the solidity of the jelly to harden..	1
70. Positively charged ions of metals may be deposited on the cathode, as atoms, when a direct current is sent through an electrolyte.	
How the chemicals in a storage battery ionize when a battery is being charged and discharged.	1
71. In a transformer the ratio between voltages is the same as that between the number of turns.	
Why different transformers are needed to run motors requiring different voltages..................	5
72. Energy in kilowatt hours is equal to the product of amperes, volts, and time (in hours) divided by one thousand.	
How direct and alternating current are measured and purchased for use in running machinery....	7
When the motor on a machine has the wattage or horsepower stamped on it......................	7
73. The mass of an atom is concentrated almost entirely in the nucleus.	
CHEMISTRY	
74. Elements are made up of small particles of matter called atoms which are alike in the same element (except for occasional differences in atomic weight; i.e. isotopes) but different in different elements.	
Why some elements are used for certain purposes..	7
Why the appearance of copper and iron are different and have different properties..........	7

TABLE II (CONTINUED)

Principle and Applications	Number of Different Industries
75. All substances are made up of small particles called molecules which are alike in the same substance (except for variations in molecular weight due to isotopes) but different in different substances.	
Why the appearance of different wood types, machinery, and parts of persons appear differently to the eyes..................................	7
Why different pieces of stock have different physical appearance because of its content within the stock..................................	6
Why certain machines do only certain heavy work..	6
Why certain metals are harder and more brittle than others..................................	4
Why there is the difference in wood, paint, tools and appearance of those materials.............	4
Why the same substance remains exactly the same unless chemically attacked....................	3
Why the same type of solution has the same usual appearance, yet has the power to bleach to a greater extent and faster..................	2
Why yarn has different tensil strengths, and has to be packed, woven, and repacked in a slightly different way.................................	1
How different types of rubber are of different elasticity.................................	1
How patented processes of cutting rubber for webbing can be completed because atomic and molecular construction is known................	1
How different yarns may be dyed or bleached a different color................................	1
76. All matter is composed of single elements or combinations of several elements and can be analyzed by chemical processes and divided into these constituents.	
How ashes remain when coal burns.................	7
Why carbon is left when oil is consumed in the boiler..................................	1
77. Every pure sample of any substance, whether simple or compound, under the same conditions will show the same physical properties and the same chemical behavior.	
Why certain metals cut easier than others........	6

TABLE II (CONTINUED)

Principle and Applications	Number of Different Industries
How wood, whether sawed, chopped, hammered still remains the same..................................	5
How a finished product is still wood when it started as wood.................................	5
When sawdust exists as a part of wood after sawing.	5
When glue is used, the sample remains the same as the original................................	4
How metal is cut, yet filings are a part of the original substance............................	4
When metal is drilled, the waste remains the same as the original................................	4
Why the vise is padded on soft metals to prevent damage to surface............................	4
Why rusting shows iron or steel present..........	4
Why the make up of metals has to be watched for flaws......................................	3
When melting tends to grind off new chunks of metal the same as the original substance......	3
When wood is the same on the stump as in a finished box..................................	2
When paint is either dry, or wet.................	2
Why all parts of machinery are made out of metal, and have the characteristics of certain types of metal....................................	2
How the tests are performed to determine the solid matter in jelly; and the acidity of vinegar; and the preservative needed for cut apples to keep..............................	1
How much bleach is needed to whiten vinegar is determined by a sampling......................	1
How juice is determined to be fully seasoned and cooked....................................	1
Why tempering unites these constituents differently......................................	1
How the solidity of a solution is found out on a sample as to the jelling capacity of cooked mixtures..................................	1
When steel is forged and retempered, it possesses the same physical aspects.....................	1
When elastic is carted in and then woven.........	1
When elastic is weighed on arrival, and departure.	1
How all types of yarn have different tensil strengths.................................	1
Why pieces of material are bleached with the same solution.................................	1
How pieces of material are dyed different colors with varying amounts of heat.................	1

TABLE II (CONTINUED)

Principle and Applications	Number of Different Industries
How yarn and rubber come in as unfinished products and go out as finished products, yet still have their individual properties........	1
How particles of yarn fly off the fast running spools, yet still have the same properties of the original................................	1
How the test for the hardness of the apple is determined................................	1
How the test for correct ingredients of extract is made......................................	1
How the percentage of the ingredients of vinegar is found by testing a sampling of that vinegar.	1
How pectin is tested to determine amount needed for hardening jelly...........................	1
How samples of cold sliced apples kept under deep freeze determine future handling of entire stock in storage.............................	1
Why one apple is used to sample a bushel as to softness and chemical ingredients............	1
78. The materials forming one or more substances, without ceasing to exist, may be changed into one or more new and measurably different substances.	
When the oxygen from the air unites with metal to form rust......................................	4
When oxidation takes place in welding...........	3
How paint is hardened...........................	3
When oxidation takes place in forging...........	1
How oil under pressure tends to produce particles when burned................................	1
How alcohol is oxidized into vinegar............	1
How coal is oxidized for heating................	1
How cooking produces a break down of chemicals into other compounds and thus obtains the finished product..............................	1
How cider becomes alcohol, and alcohol becomes acetic acid by oxidation.....................	1
How chemical energy of worms turn alcohol into vinegar..	1
Why carbon is left when oil is consumed in the boiler...	1

TABLE II (CONTINUED)

Principle and Applications	Number of Different Industries
How ashes remain when coal burns.................	1
79. Oxidation always involves the removal or sharing of electrons from the element oxidized while the reduction always adds or shares with the element reduced.*	
80. Oxidation and reduction occur simultaneously and are quantitively equal.*	
Why machinery is rusted when not oiled...........	5
How grinding is accomplished......................	4
How paint protects and shields surfaces..........	4
When burning of metal takes place (cutting)......	4
When the welding process used a brass solder, the metal is oxidized to burning and thus burns out the oxygen, and oxidizes the welded stock.	4
When water and air combine to rust stock and equipment..................................	4
When forging takes place, oxidation takes place on the surface, but reduction takes place in the air..................................	3
When the arc welder is used to burn through stock.	3
When oil is heated and is then used for burning..	2
When the forge is used..........................	1
How dyeing solution affects material............	1
How the room needs humidifying to prevent oxidation of yarn................................	1
When alcohol is oxidized into acetic acid........	1
How metal strips are rusted by acid and air......	1
How chemical tests are made to determine acidity, strength, and solidity of products............	1
Why paint dries quickly.........................	1
Why oil is used to give a hotter flame..........	1
How a bleach solution cleans material...........	1
How dye completes the job of reduction..........	1
How the room is humidified to prevent oxidation..	1
Why apples become rotten........................	1
How cooking tends to oxidize and to reduce water from jelly................................	1
How oxidation of prunes provides prune juice.....	1
How acetic acid oxidizes metal fittings..........	1
How sulphur dioxide gas prevents oxidation of the apple and prevents the soft apple from decaying quickly................................	1

*All Applications assigned to principle number 80 are also considered to be assigned to principle 79.

TABLE II (CONTINUED)

Principle and Applications	Number of Different Industries
When bleach is used to make yarn whiter..........	1
How small particles of vinegar are found in the air and tend to rust metal which it comes into contact with..............................	1
81. The exchange of the negative and positive ions of acids and bases results in the formation of water and a salt.	
82. Electrolytes dissolved in water exist partially or completely as electrically charged particles called ions.	
How sodium hydroxide bleach ionizes when in solution..	1
How the chemicals in a storage battery ionize when a battery is being charged and discharged.	1
83. All matter is made up of protons, neutrons, and electrons.	
84. The electrons within an atom form shells about the nucleus, each of which contains a definite number of electrons.	
85. The solubility of solutes is affected by heat, pressure, and the nature of the solute and solvent.	
Why glue needs to be heated in order to be used..	3
Why paint tends to change in consistency in different drying stages.........................	3
Why solutes are mixed under specific directions to do the most good..........................	2
Why sawdust tends to make the consistency of stain rougher and thicker.....................	1
Why all the dyeing or bleaching solutions are maintained at the correct temperature for greater effectiveness..........................	1
Why special dyes are originated and used to dye elastic a certain color......................	1
Why jelling takes place best at the correct conditions within the jelly solution.............	1

TABLE II (CONTINUED)

Principle and Applications	Number of Different Industries
How solubility of dextrose is greater than that of sugar in jelling..............................	1
How sulphur dioxide solution is made to prevent spoiling, of cut apples, and the solution has to be strengthened occasionally...........	1
How vinegar is speeded up in production by an increase of heat..................................	1
How water is used to dissolve jelly and juices, and steam is used to speed the drying and sterilizing process............................	1
Why particles of paint or water tend to make a solution..	1
How water and steam are used to wash the residue of jelly and juice which coat the machinery...	1
86. The valence of an atom is determined by the number of electrons it gains, loses or shares in chemical reactions.	
87. Most atoms have the property of losing, gaining, or sharing a number of out shell electrons.	
88. The energy shown by atoms in completing their outer shell by adding, losing or sharing electrons determines their chemical activity.	
89. The properties of the elements show periodic variations with their atomic numbers.	
90. Each combustible substance has a kindling temperature which varies with its condition but may be greater or less than the kindling temperature of some other substance.	
How kindling temperature of oil is used in drying wood...	4
Why paint and varnish have to be safeguarded to prevent explosion...............................	4
Why air is supplied to the fire to increase the heat..	3
Why the arc welder burns different metals faster.	3
Why stoves using wood become hot more quickly than those using coal............................	2

TABLE II (CONTINUED)

Principle and Applications	Number of Different Industries
Why pressurized oil is used to obtain a hotter fire	1
Why elastic has a higher kindling temperature than the yarn	1
Why the kindling temperature is lower in a vacuum	1
How the kindling temperature of fire heats up other ingredients so that they simmer, boil and then burn	1
91. Matter may be transformed into energy and energy into matter; the sum total, matter plus energy, remains constant.	
How food produces mechanical energy in humans	7
How fires produce heat leaving ashes behind as well as gases	5
Why burning of coal releases gases	4
How paint tends to harden and become gaseous in doing so	4
How electricity is turned into light by a glowing filament	4
Why arc welding tends to burn through metal	3
92. The total mass of a quantity of matter is not altered by any chemical or physical changes occurring among the materials composing it.	
How bleach is effective in whitening but doesn't weaken yarn chemically	2
How dyeing is used to change colors of materials chemically yet no actual physical change in the materials is noted	1
How carbon tends to be deposited when oil is burned, but all results in heat, gases and materials deposited which weigh the same as the original substance	1
How all ingredients used in the entire industry in different products still is retained in gaseous, liquid, or solid forms and tend to weigh equally in amounts from beginning to end	1
93. The rates of many reactions are affected by the presence of substances which do not enter into the completed chemical reaction.	
Why bleaching uses several mixed chemicals while only a few enter chemical combination	2

TABLE II (CONTINUED)

Principle and Applications	Number of Different Industries
How cut apples are preserved by a catalytic agent that doesn't influence flavor.................	1
How the chemistry of jelling, testing and mixing provides many conditions that are needed to carry reactions out, but do not enter chemically into actual solution....................	1
How pumice is used to solidify apples but doesn't enter into cider or apple juice...............	1
94. Acids and bases in water solution ionize to give hydrogen and hydroxyl ions, respectively, from their constituent elements.	
Why water is used with the heavy base bleach to dilute it.....................................	1
Why acetic acid partially ionizes into ions......	1
Why battery solution tends to produce increasingly more water as discharging proceeds.........	1
95. The ingredients of a solution are homogeneously distributed through each other.	
Why liquid glue has the same physical qualities and chemical qualities whether in a large or in a small mass...............................	5
Why stain is generally mixed and produces the same qualities in small or large quantities...	2
Why the entire bleaching solution is effective...	1
Why all of a dyeing solution has the power to dye.	1
How the colors and ingredients have to be mixed thoroughly to obtain juice, vinegar, orjelly from apples.................................	1
How the settling out of any of the ingredients tends to dispose some of the strength of the product.....................................	1
96. When different amounts of one element are found in combination with a fixed weight of another element (in a series of compounds) the different weights of the first element are related to each other by ratios which may be expressed by small whole numbers.	

TABLE II (CONCLUDED)

Principle and Applications	Number of Different Industries
How the steel formula is determined for producing steel..	3
97. Atoms of all elements are made up of protons, neutrons, and electrons, and differences between atoms of different elements are due to the number of protons and neutrons in the nucleus and to the configuration of electrons surrounding the nucleus.	
GEOLOGY	
98. When elevations or depressions are created upon the surface of the earth, the elevations are usually attacked by the agents of erosion, and the materials are carried to the depressions.	
99. Streams, generally, are lowering the surface land in some places and building it up in other places.	
100. Rocks may be formed by the compacting and cementing of sediments.	
101. The earth's surface may be elevated or lowered by interior forces.	
102. Strata of rocks occur in the earth's crust in the order in which they were deposited, except in the case of overthrust faults.	
103. Earthquakes are produced by the sudden slipping of earth materials along faults.	

Findings Table II: Of the defensible assignments of applications to principles, 52 made to 36 principles were found in all seven industries; 158 made to 40 principles were found in only six industries; 92 made to 42 principles were found in only five industries; and 112 made to 42 principles were found in only four industries. Thus, 410 different assignments of applications found in a majority of the seven industries were defensibly made to 65 different principles. Complete totals show 1284 different assignments of applications found in one or more of the seven industries were defensibly made to 82 principles of physical science.

A total of 82, or 79.6 percent of the 103 principles of physical science developed in whole or in part in grades seven through twelve of the public school had from one to fifty-eight applications in one or more of the seven industries.

A total of seventy-four applications were not defensibly assigned to at least one of the 103 principles from Wise's list of 272 principles of physical science and were therefore placed in the Appendix.

CHAPTER IV

SUMMARY, CONCLUSION AND RECOMMENDATIONS

RESTATEMENT OF THE PROBLEM

This investigation is made to determine the number of 103 principles of physical science, considered by a majority of a group of specialists in the teaching of science to be essential for inclusion in an integrated course of physical science for the senior high school, which are developed in whole or in part in grades VII - XII, inclusive, of the Littleton (Massachusetts) Public School; and to determine the applications of these 103 principles of physical science found in the industries of Littleton, Massachusetts.

SUMMARY OF THE TECHNIQUES EMPLOYED

A complete list of 272 of Wise's principles of physical science was presented to each science teacher in grades VII - XII, inclusive, of the Littleton (Massachusetts) Public School. Each teacher indicated for each principle the grade, or grades, at which the principle was taught. The 103 principles of physical science considered essential and desirable by five specialists in the teaching of science for inclusion in an integrated course of physical science in grades X - XII, inclusive, were then removed from the list of 272 principles of physical science so checked.

A perusal of each of seven industries of Littleton, Massachusetts for applications of the 103 principles of physical science was completed. A total of fifty applications was assigned at two different times, three months apart, by the investigator to the principles which they best represented, thus a coefficient of reliability of 0.88 was obtained. The validity was ascertained by submitting this tentative list of 1296 different assignments of applications to the 103 principles to a specialist in the teaching of science.

SUMMARY OF THE FINDINGS

A total of 103 principles of physical science, 73 of physics, 25 of chemistry, and 6 of geology, was considered by the science instructors to be developed in whole or in part on at least one grade level from grades VII - XII, inclusive. Of the total of 103 different principles, not one was developed in whole or in part in all six grades, 6 were developed in five different grades, 22 in four grades, 43 in three grades, 28 in two grades and 4 in only one grade. Thus, repetition of attempts to develop a principle at increasingly higher grade levels is properly shown.

The number of different principles taught at different grade levels were: grade VII, 12; grade VIII, 26; grade IX, 0; grade X, 77; grade XI, 96; and grade XII, 96.

This indicates an attempt to develop an understanding of an increasingly greater number of principles at successively higher grade levels.

A total of seventy-one of the 103 principles were first introduced at the senior-high-school level, grade X or later. Thirty-two of the principles were first introduced at the junior-high-school level, twelve in grade VII and twenty in grade VIII.

Of the defensible assignments of applications to principles, 52 made to 36 principles were found in all seven industries; 158 made to 40 principles were found in only six industries; 92 made to 42 principles were found in only five industries; and 112 made to 42 principles were found in only four industries. Thus, 410 different assignments of applications found in a majority of the seven industries were defensibly made to 65 different principles. Complete totals show 1284 different assignments of applications found in one or more of the seven industries were defensibly made to 82 principles of physical science.

A total of 82 or 79.6 percent of the 103 principles of physical science developed in whole or in part in grades seven through twelve of the public school had from one to fifty-eight applications in one or more of the seven industries.

There is little or no use in the science program offered in the secondary school of Littleton, Massachusetts of community resources found within the industries of the town. This need not be so for a majority of the scientific principles taught in the schools have applications in local industry which could be used in developing a functional understanding of these principles. It is readily seen that physical science in the school could provide more intelligent citizens with respect to local industry by acquainting the pupils with practical applications of the principles of physical science found in local industry.

Because of a study of the applications of those principles, pupils would, in the light of other studies of retention of learning, probably find a marked increase in their ability to apply the principles to solve new problem situations with which they are confronted.

RECOMMENDATIONS

This investigation suggests the following four important items for further investigation: (1) development of a testing program that will present adequate evidence of the educational outcomes developed in terms of the principles, and applications of the principles found in the seven industries of Littleton, Massachusetts; (2) revision of the physical science offerings in accordance with the results obtained in the testing program; (3) determination of the place of experiences in the community related to physical

science in terms of physical science taught in courses from grades VII - XII, inclusive; (4) revision and reconstruction of the program of studies to permit visitation to local industries to study the applications of principles of science.

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APPENDIX

LIST OF APPLICATIONS NOT VALIDLY ASSIGNED TO AT LEAST ONE OF THE ONE-HUNDRED THREE PRINCIPLES FROM WISE'S LIST OF TWO HUNDRED SEVENTY-TWO PRINCIPLES OF PHYSICAL SCIENCE

When yarn is dyed.
How less heat is needed for a substance being cooked in a partial vacuum.
Why steam and tanks of bleach or dye solution tend to maintain heat for a longer period than air coming into contact with them.
How the dried webbing cools off more quickly than the solution wrung from it before drying.
Why the jelly has to be cooled quickly by a spray to room temperature to keep the flavor intact.
Why more heat has to be given to a solution than the kettle which contains the solution to equalize the temperature.
Why steam is used to sterilize jars, barrels, and equipment because the materials heat and cool faster than the hot water would.
Why gloves are worn more when handling rough lumber than when working on planed lumber.
How the conveyor seems to strike apples and damage skin when they are being graded.
Why windows seem to give more direct light than flourescent lighting.
When the hand takes hold of the hammer.
When the machines are handled.
How the hammer strikes the bolt.
How the yarn tends to be touching part of the grooves as it goes through the holes in the machine.
How less heat is needed to exert as much pressure above the liquid and on the liquid in a partial vacuum.
How the jelly and juice take the shape of their containers and are stored for later use.
When two different rolls of yarn and elastic are woven together, there is a continual transfer of heat energy.
How apples once frozen cannot be thawed without quickly spoiling.
When the spray gun is used and volume increases the sound becomes higher.
Why rising heat is noticed "wavering" up from forge or hot object.
How paint is spread onto wood by spray gun.
Why heat rises in "waves" from radiators, boilers, or drying tanks.
How stretched webbing being rolled onto spools tends to vibrate according to the vibration that the receiving spool tends to transmit to it.

APPENDIX (CONTINUED)

How the paddle tends to give out "waves" as it stirs mixture of jelly, juice, etc..
How pumping steam under pressure provides "waves of energy" in the pressure gauge.
How mechanical energy seems to haul the conveyors in short, small "waves".
How vibration of machinery causes bottles to knock against each other monotonously at one pitch.
Why the day shift does more work on fine settings because of the better lighting conditions.
Why lights dim when extra machinery runs.
Why electrical power is cheaper than regular labor to do the same kind of work better.
Why the goods brought in are weighed, and the completed product is weighed on discharge from the industry.
Why wear and tear is less upon a smooth surface.
Why when the room is hot workers become wet, give off moisture in an attempt to keep cool.
How the crystals of jelly are noted in determining tests of solidity of matter contained within the jelly.
Why certain amounts of machinery are used more carefully to prevent damage to products.
Why welding or burning emits a different color when different materials are used.
How water vapor regulates the tensile strength of yarn in weaving.
How solvent is pasteurized to prevent any solute being developed any stronger.
How glue plus heat equals stickiness, adhesion, and gas.
How chemicals produce a mechanical change of color.
Why paint tends to solidify in the cans, yet may be thinned by turpentine.
Why paint and stain hardens more quickly when warm air passes over painted surfaces.
Why soldering compound is used to produce a harder joint.
How heat helps to change alcohol to vinegar faster and more quickly.
How any recipe is followed in making bleach and dye.
How the tensile strength of yarn is found by the elements composing it.
How recipes are followed to obtain the finished product of hardened jelly, healthy prune juice, and tart vinegar.
How the wood bundles and reserve stocks are weathered.
Why a second adjacent punch hole tends to guide into the first deeper punched hole.
Why stock is center-punched for drilling.
How piles of stock are used up.
How yarn ends tend to wear out on the machinery and break.
Why the elastic is covered with yarn so that it will last longer.

APPENDIX (CONCLUDED)

How jelly and juice have to be screened before going into jars to prevent sediment entering into final product.
How different amounts of vibration produce a better disposal of waste stock.
How nails tend push the surface out when they become bent in the wood.
How worms eat holes in logs thus lowering the solid part of the log.
How a prune fills out in water.
How apple juice is separated from apple mash by filtering.
How metals when piled up are arranged in layers.
Why wrenches arrange themselves in layers when thrown on top of each other.
How boxes are piled to facilitate more room.
How boards and logs are piled to make them more compact.
How cabinets are arranged for better drying.
How leatherette is put on for protection of wood.
How all types of yarn, elastic, and webbing are rolled, folded, or woven into layers and then deposited into packing boxes.
How filtering deposits solids of the apple in layers.
How conveyors tend to arrange materials in layers when they are deposited at the end of the belt.
Why the vibrating machines tend to shift part of the metal dustpiles into faults.
Why vibrations tends to shape waste particles of sawdust down shutes.
How folded twist tends to be tangled in folds when other folds slip down onto the piled twist material.
How rolls of webbing tend to slip and come apart as faults do when being packed or graded.
Why it takes less heat to heat pectin extract in a partial vacuum and boil it down into a stronger solution.
Why a separate generating plant is used to produce cheaper power to run the factory.